JOURNAL OF ANIMAL SCIENCE

Published Quarterly

by the

American Society of Animal Production

AUGUST

1961

Volume 20 Number 3

EDITORIAL BOARD

C. E. TERRILL, *Business Manager*

A. B. CHAPMAN, *Editor and Chairman* — R. H. DUTT, *Associate Editor*

E. E. BARTLEY (1962)*
D. E. BECKER (1963)
R. O. BERRY (1961)
T. N. BLUMER (1964)
D. CHAMBERS (1961)
J. W. COLE (1965)
G. K. DAVIS (1962)
K. E. GREGORY (1963)
W. HANSEL (1964)
V. W. HAYS (1964)
W. P. LEHRER, JR. (1962)
I. L. LINDAHL (1964)
L. E. LLOYD (1965)
J. H. MEYER (1964)
T. W. PERRY (1961)

* Terms expire on December 31 of years indicated.

OFFICERS OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

H. H. STONAKER, *President*
T. J. CUNHA, *Vice President*
C. E. TERRILL, *Secretary-Treasurer*
W. A. COWAN, *North-Atlantic Vice President*
O. F. PAHNISH, *Western Vice President*
W. GIFFORD, *Southern Vice President*
J. K. LOOSLI, *Director*

Subscriptions. Correspondence concerning subscriptions, purchase of single copies and back issues and related business should be addressed to the Business Manager, C. E. Terrill, Animal Husbandry Research Division, Agricultural Research Center, Beltsville, Maryland. Subscription price for non-members for Volume 20 (1961) is $7.00 in U. S. and Canada, $7.50 in rest of North and South America, and $8.00 in other places. Checks should be made payable to the American Society of Animal Production. Foreign subscribers are requested to remit by International money order or by a draft on a New York bank.

Address Change. Notice of change in address should be received by the Business Manager at least 40 days previous to month of Journal issue. Lost copies, owing to change in address, cannot be supplied unless adequate notice has been given.

Missing Copies. Claims for missing copies should be sent to the Business Manager within 90 days of publication date. Such claims will be allowed only if the Journal or the printing company is at fault.

Membership. Application is invited from persons with interest in animal science and livestock production. The Vice President of the Society is chairman of the Membership Committee. Annual dues in the Society which include a subscription to the Journal are $6.00 in U. S. and Canada, $6.50 in rest of North and South America and $7.00 in other countries.

Manuscripts. Address manuscripts and correspondence concerning them to the Editor, A. B. Chapman, Department of Genetics, University of Wisconsin, Madison 6, Wisconsin. At least one of the authors of a manuscript should be a member of the Society. Publication of papers by non-members requires the approval of the Executive Committee. See "Information for Contributors" regarding manuscript preparation.

Reprints. Reprints of papers in the Journal are obtainable only from the authors or their institutions. Authors of papers accepted for publication are required to make a minimal purchase of 100 reprints.

News and Notes. Announcements about meetings, personnel changes and other items of interest to the Society may be sent directly to the Editor. Similar items relating to the USDA and Federal Agencies are received from James O. Grandstaff, State Experiment Stations Division, Agricultural Research Service, U. S. Department of Agriculture, Washington 25, D. C.

Second class postage paid at Albany, N. Y.

Boyd Printing Company, Inc., 49 Sheridan Ave., Albany 10, N. Y.

Journal of

ANIMAL SCIENCE

VOLUME 20 AUGUST, 1961 NUMBER 3

CONTENTS

	Page
Factors Affecting Net Calf Crop in Beef Cattle. J. N. WILTBANK, E. J. WARWICK, E. H. VERNON and B. M. PRIODE	409
Rate of Passage of Feeds Through the Digestive Tract of Holstein Cows. P. R. SHELLENBERGER and E. M. KESLER	416
Influence of Early Weaning on Creep-fed Milk Lambs When Weaned on Weight or Age. DON G. BROTHERS and J. V. WHITEMAN	420
Production of a Population with Equal Frequency of Genes from Three Parental Sources. EDWIN LAUPRECHT	426
Effect of Levulinic Acid on Digestibility, Fatty Acid Production and Microbial Activity in Dairy Heifers and Wethers. D. E. WALDERN, W. K. ROBERTS, T. H. BLOSSER and I. A. DYER	429
Influence of Dietary Calcium and Zinc on Calcium-45, Phosphorus-32 and Zinc-65 Metabolism in Swine. R. K. BERRY, M. C. BELL, R. B. GRAINGER and B. G. BUESCHER	433
Improvement of Barley Rations for Swine. III. Effect of Fiber from Barley Hulls and Purified Cellulose in Barley and Corn Rations. L. M. LARSEN and J. E. OLDFIELD	440
Hemoglobin Levels of Lambs from Birth to Eight Weeks of Age and the Effects of Iron-Dextran on Suckling Lambs. R. C. HOLZ, T. W. PERRY and W. M. BEESON	445
Energy Requirements of Grazing Steers. R. P. KROMANN, J. H. MEYER and J. L. HULL	450
Influence of Sex and Sire on Weaning Weights of Southwestern Range Calves. O. F. PAHNISH, E. B. STANLEY, RALPH BOGART and [illegible] B. ROUBICEK	454
Use of Hematological Techniques in Study of "Snorter" Dwarfism. R. S. TEMPLE and L. N. HAZEL	459
Response of the Young Pig to Levels of Dietary Potassium. A. H. JENSEN, S. W. TERRILL and D. E. BECKER	464
Effect of Four Maturity Stages of Timothy Hay on Its Chemical Composition Nutrient Digestibility and Nutritive Value Index. L. E. LLOYD, H. F. M. JEFFERS, E. DONEFER and E. W. CRAMPTON	468
Studies on Bovine Ocular Squamous Carcinoma "Cancer Eye". XI. Effects of Sunlight. DAVID E. ANDERSON and PHILIP E. SKINNER	474
Effect of Physical Form of the Ration on Steer Performance and Certain Rumen Phenomena. A. E. CULLISON	478
Lignin Excretion by Cattle Fed a Mixed Ration. C. J. ELAM and R. E. DAVIS	484

FACTORS AFFECTING NET CALF CROP IN BEEF CATTLE [1, 2]

J. N. WILTBANK,[3] E. J. WARWICK,[3] E. H. VERNON [4] AND B. M. PRIODE [5]

United States Department of Agriculture and the Virginia and Louisiana Agricultural Experiment Stations

THE proportion of beef cows entering a breeding herd which wean a calf as a result of being bred in that breeding season has been shown to vary from year to year (Baker and Quesenberry, 1944; Burke, 1954; Lindley *et al.*, 1958) and from area to area (Ensminger *et al.*, 1955). The importance of failure to conceive and of prenatal embryonic death, was pointed out by Baker and Quesenberry (1944). They reported that of the cows bred in an experimental herd of Herefords at Miles City, Montana, 85.6% calved and 81.0% weaned calves.

The purpose of this study was to determine the relative importance of the various points at which reproductive failure occurs in the beef cow, and to examine some of the reasons for failure to conceive.

Materials and Methods

The cattle studied included Angus, Herefords and Shorthorns at the Beef Cattle Research Station, Front Royal, Virginia, and Brahman and two strains based on Brahman-Angus and Africander-Angus crossbred foundations at the Iberia Livestock Experiment Station, Jeanerette, Louisiana. For convenience, the term "Zebu breeds" will be used in reference to Brahman, the Brahman-Angus and the Africander-Angus groups.

This study was conducted during the 1956 and 1957 breeding seasons and was continued until the calves from these matings were born and weaned. Cows were bred in individual sire pastures during a breeding season of approximately 75 days. Breeding started approximately April 1 at the Iberia Station and April 10 at the Front Royal Station. The number of cows allotted to each bull was varied from 9 to 43 with most herds having between 15 and 30 cows.

Breeding dates were obtained in both seasons at Front Royal and in 1956 at the Iberia Station by placing a multi-purpose grease containing a dry non-lead paint pigment on the brisket of each bull in a breeding herd at least twice daily. Daily observations were made and a breeding date was recorded for a cow on the first day grease was noted on her tailhead or rump. Actual matings were observed in some cases.

Rectal examinations of the reproductive organs were made at specified intervals to determine which cows were pregnant, to estimate the magnitude of losses which occurred after conception and to help determine the approximate time after conception that losses occurred. In both seasons at Front Royal and in 1957 at the Iberia Station, examinations were made at end of the breeding season and cows not diagnosed pregnant were reexamined 35 days later. All cows were examined again in October, or approximately 7 months after beginning of the breeding season. In 1956, examinations at the Iberia Livestock Station were made in October only. At the earlier pregnancy examinations, the age of fetus was estimated by its approximate size. These estimates were used to help determine the accuracy of the breeding dates obtained (Wiltbank *et al.*, 1956).

Heifers were bred to calve for the first time when 3 years of age at both stations. Some accidental matings, however, occurred at Front Royal and a group of Angus and Hereford heifers calved as 2-year-olds. These heifers have been included in the data. Some pregnant cows at the Front Royal Station were culled for reasons other than reproduction after the pregnancy examination in October. The data from these cows were used to the extent possible. Information on numbers culled is given in footnotes in the tables.

Calving at both stations was on pasture with pastures being checked at least once

---

[1] Contributing to Southern Regional Project S-10.

[2] Published with the approval of the Directors of Virginia and Louisiana Agricultural Experiment Stations.

[3] Beef Cattle Research Branch, Animal Husbandry Research Division, ARS, Agricultural Research Center, Beltsville, Maryland.

[4] Beef Cattle Research Branch, Animal Husbandry Research Division, ARS, Iberia Livestock Experiment Station, Jeanerette, Louisiana.

[5] Beef Cattle Research Branch, Animal Husbandry Research Division, ARS, Beef Cattle Research Station, Front Royal, Virginia.

TABLE 1. COWS PREGNANT AND CALVING AND CALF DEATH LOSSES

Station, season and breeding group	Cows in breeding herds	Cows diagnosed pregnant				Cows diagnosed pregnant in October but failed to calve	Calf death losses			Net calf crop[a]
		Initial check		Check in October			At or near birth	Birth to 2 weeks of age	2 weeks of age to weaning	
Front Royal	No.	No.	%	No.	%	No.	No.	No.	No.	%
1956 season										
Angus	145	132	91	130[b]	90	0	4	2	2	84
Hereford	135	118	87	112[b]	83	1	4	2	0	78
Shorthorn	173	148	86	146[b]	84	1	14	13	0	66
Total	453	397	88	388	86	2	22	17	2	75
1957 season										
Angus	139	133	96	130[c]	93	5	19	2	4	68
Hereford	152	133	88	133[c]	87	2	15	1	3	73
Shorthorn	138	114	84	114[c]	84	3	19	3	0	64
Total	429	380	88	377	88	10	53	6	7	68
Iberia										
1956 season										
Brahman-Angus	133	...[d]	..	87	65	4	4	1	2	57
Afri-Angus	58	...	..	48	83	3	0	1	1	74
Brahman	35	...	..	28	80	0	1	1	0	74
Total	226	...	..	163	72	7	5	3	3	64
1957 season										
Brahman-Angus	140	119	85	114	81	2	6	18	0	63
Afri-Angus	63	55	87	54	86	3	3	5	0	68
Brahman	33	25	76	25	76	1	2	8	0	42
Total	236	199	84	193	82	6	11	31	0	61

[a] Calculations based on assumption that death losses in calves of pregnant cows sold would have been the same as for cows actually calving.
[b] 7 Angus, 2 Hereford, and 18 Shorthorn pregnant cows sold before calving.
[c] 20 Angus, 8 Hereford, and 4 Shorthorn pregnant cows sold before calving.
[d] Iberia cattle not checked until October in 1956.

each day during the calving season. All calves born were identified and weighed. A calf was considered stillborn if found dead without identification mark at the time the pastures were checked.

Vibrio fetus infection was suspected in some herds at Front Royal and samples of vaginal mucus were taken and cultured from two animals in each herd in 1956 and from suspected breeding herds in 1957. This procedure revealed the presence of *Vibrio fetus* in part of the herds.[6] Data from infected herds have been omitted from all tables, except table 7, where the effect of the infection is indicated.

The length of the intervals from calving to first estrus could not be precisely determined for all cows from these data. However, on the assumption that cows had not been in estrus since calving, if they did not have a breeding date in the first 24 days of the breeding season, it was possible to make estimates of the proportion of all cows having intervals longer than a specified number of days. Proportions of intervals over 80 days, over 90 days, and over 100 days were calculated.

[6] Samples were taken and cultured by Dr. A. H. Frank, Animal Disease Division, ARS, Beltsville, Maryland (Bryner and Frank, 1955).

Results and Discussion

Numbers of cows pregnant at different pregnancy examinations and calf death losses are shown in table 1. Failure to conceive or embryonic death occurring before first examination for pregnancy represented the most important factor in reducing calf crop; second in importance were losses occurring at or near the time of birth. The difference between years in the magnitude of losses at or near birth may have been the result of extremely cold, wet weather occurring at both stations at calving time in 1958.

The losses at calving time were larger than those reported by Woodward and Clark (1959) and by McCormick *et al.* (1956). The large yearly variation suggests the need for adoption of adequate management procedures to meet changing climatic conditions so that losses at birth can be lowered when weather is unfavorable. Losses of smaller magnitude occurred as the result of embryonic death after pregnancy had been diagnosed.

TABLE 2. BREEDING PATTERN OF OPEN COWS AND HEIFERS

Station and breeding group	No. open	No. not showing heat	No. bred one time		No. bred 2 or more times
			Last 30 days of breeding season	Prior to last 30 days of breeding season	
Front Royal					
Angus					
Heifers and dry cows	5	0	0	1	4
Cows suckling calves	14	1	1	3	9
Hereford					
Heifers and dry cows	6	0	0	1	5
Cows suckling calves	30	7	4	7	12
Shorthorn					
Heifers and dry cows	24	3	0	3	18
Cows suckling calves	25	2	7	2	14
Iberia					
Zebu and Zebu crosses[a]					
Heifers and dry cows	26	2	2	7	15
Cows suckling calves	37	12	6	6	13

[a] 1956 only.

The frequency of calf losses from 2 weeks after birth but before weaning was also small.

Study of the breeding pattern of dry cows and heifers which did not conceive during the breeding season indicated that more than half were bred at least twice during the breeding season (table 2). One Shorthorn and two Zebu heifers failed to reach puberty before the end of the breeding season and two other Zebu heifers reached puberty so late they were bred only once late in the breeding season. The breeding pattern of the open cows suckling calves differed from that of the open heifers and dry cows. In the former group a much higher proportion either did not come in estrus during the breeding season or came in estrus so late they had only one opportunity to be bred. The large proportion falling into this group tends to emphasize the importance of shortening the interval from calving to first estrus in most of the breeds.

The conception rate at first service varied from 39% in Brahman-Angus to 80% in the Brahman (table 3). There was a decrease in proportion conceiving at second service in most of the breeds and the percent conceiving at third service was considerably lower in all breeds except the Brahman-Angus. The difference in the average number of services required per conception (total number of services divided by number of cows becoming pregnant) among the British breeds was significant ($P \cong .05$) and was highly significant among the Zebu groups ($P < .01$) when tested by analysis of vari-

TABLE 3. COWS AND HEIFERS SETTLING AT VARIOUS SERVICES

Station and breeding group	1st service		2nd service		3rd service		Services per conception	Services—cows that conceived
	Bred	Conceiving	Bred	Conceiving	Bred	Conceiving		
	Total no.	%	Total no.	%	Total no.	%	Av. no.	Av. no.
Front Royal								
Angus	283	70	81	63	25	48	1.49	1.34
Hereford	280	66	83	71	14	43	1.53	1.31
Shorthorn	306	61	107	51	38	42	1.76	1.38
Total	869	65	271	61	77	44	....	....
Iberia[a]								
Brahman-Angus	127	39	61	41	25	48	2.50	1.56
Africander-Angus	55	73	13	54	2	50	1.42	1.19
Brahman	30	80	6	67	0	..	1.21	1.14
Total	212	54	80	45	27	48	....	....

[a] 1956 only.

ance. These differences among the Front Royal breeds nearly disappeared when only the number of services by the cows becoming pregnant were considered, thus indicating that the differences between breeds in the average number of services required per conception were largely a difference in the proportion of cows which conceived. Differences among the breeding groups at the Iberia Station were not statistically significant. The average numbers of services per conception reported here are larger for the Shorthorn and Brahman-Angus and fewer for the other four breeds than the comparable figures of 1.63 and 1.7 reported by Lasley and Bogart (1943), and Lindley *et al.* (1958).

A decrease in conception rate resulted from the use of yearling bulls (table 4). This decrease was small and non-significant ($P > .05$) in all groups except the Brahman-Angus. Of the Brahman-Angus cows bred to yearling bulls there were 34% fewer which settled on first service ($P > .05$) and 26% fewer which were diagnosed pregnant ($P < .05$) than in cows bred to all other ages of bulls.

The breeding performance of heifers, dry cows and cows suckling calves was compared. Breed groups were combined when little or no difference was apparent between them (table 5). A smaller proportion of dry cows than lactating cows or heifers became pregnant in all breeds except the Brahman. The proportion of cows which were bred during the first 21 days of the breeding season was smaller for lactating cows than for heifers or dry cows. Differences were especially apparent between lactating cows of the Hereford, Shorthorn, Brahman-Angus and Brahman and the corresponding heifers or dry cows.

The proportion of animals for which no breeding date was recorded varied from 0 to 18% in the different breed groups. The proportion of animals not showing estrus was highest in the Zebu cows suckling calves. The data permit no estimate of whether the observed differences at the two stations between lactating cows are the result of breed differences or location effects.

The proportion of heifers and wet cows which conceived at first service at Front Royal was similar but conception rate of dry cows was lower. At the Iberia Station the low first-service conception rate of all groups in the Brahman-Angus breed is striking. Other groups had higher and essentially similar rates.

The reproductive performance of nursing cows of various age groups was studied (table 6) with Brahman cows being omitted because of small numbers. Several age groups have been combined because differences were small.

TABLE 4. EFFECT OF AGE OF BULL ON CONCEPTION RATE

Station and breeding group	Bulls	Cows bred	Conceived 1st service	Cows served, diagnosed pregnant
	No.	Av. no.	%	%
Front Royal				
Angus				
2 yrs. or older	7	23.0	72	96
yearling	6	20.0	68	94
Hereford				
2 yrs. or older	9	25.6	67	90
yearling	3	12.3	51	84
Shorthorn				
2 yrs. or older	7	26.6	58	88
yearling	7	19.1	57	81
Iberia				
Brahman-Angus				
2 yrs. or older	3	23.7	55[a]	80[b]
yearling	3	18.7	21[a]	53[b]
Africander-Angus				
2 yrs. or older	2	13.0	72	88
yearling	2	14.5	70	84.5
Brahman				
2 yrs. or older	1	19.0	79	89
yearling	1	11.0	82	100

[a] Approaches significance at .05 level.
[b] Significant at .05 level.

TABLE 5. COMPARATIVE BREEDING PERFORMANCE OF HEIFERS, DRY COWS AND COWS SUCKLING CALVES

Station and breeding group	No.	Bred 1st 21 days of season %	Not showing heat during season %	Conceived 1st service %	Diagnosed pregnant %
Front Royal[a]					
2 yr. old heifers	162	93	1	64	91
Dry cows	108	86	2	50	81
Cows suckling calves					
Angus	223	82	0.4	73	94
Hereford	202	65	3	67	85
Shorthorn	187	64	1	64	87
Iberia[b]					
Brahman-Angus					
2 yr. old heifers	31	74	0	32	71
Dry cows	15	80	0	0	33
Africander-Angus and Brahman					
2 yr. old heifers and dry cows	37	84	5	77	81
Cows suckling calves					
Brahman-Angus	87	57	7	46	69
Africander-Angus	34	76	6	72	88
Brahman	22	50	18	78	73

[a] 1956 and 1957.
[b] 1956 only.

The proportion diagnosed pregnant was lower in younger cows than in the older cows of all breeds except the Shorthorn. The most important reason for this appears to be the longer interval from calving to first estrus with the younger cows also having lower conception rate at first service in the Angus.

It was impossible to determine exactly the length of the interval from calving to first estrus from these data. Three items in table 6, however, indicate that the younger cows had longer intervals. First, the proportion bred during the first 21 days of the breeding season is larger in the older cows than in the younger ($P<.05$ for Brahman-Angus; all other groups $P>.05$). Second, the proportion for which no breeding date was recorded is smaller for the older cows than for the younger cows. Third, the proportion of the intervals from calving to first estrus, estimated to be over 80 days in length, over 90 days in length or over 100 days in length is smaller for the older cows in most instances. This is not in agreement with the results reported by Warnick (1955) who reported that age had no effect on the length of the interval from calving to first estrus.

The length of the interval from calving to first estrus would appear to be somewhat shorter in the Angus than in the other groups when we consider the three items in table 6 mentioned before. From this and also from the discussion of table 2 and table 5, it would appear that shortening the length of the interval from calving to first estrus would be important in increasing the calf crop in beef cows. The lower conception rate for young cows in some breeds is in agreement with the work of Lasley and Bogart (1943).

In herds found to be infected with *Vibrio fetus*, fertility was markedly reduced. A herd was designated as an infected herd if the catalase positive vibrio organism was isolated from one animal in the herd (Frank *et al.*, 1958). The proportion of cows diagnosed pregnant in the infected herds was smaller and the number of services required per conception was larger (table 7). When only the cows which conceived during the breeding season are considered, the average number of services required per conception was still considerably higher than in non-infected herds. In one Shorthorn herd, included here as an infected herd, it is thought that the bull became infected approximately half way through the breeding season. It is believed that this occurred when he entered another pasture and bred a cow infected with *Vibrio fetus*. Most of the "infected" Shorthorn cows which settled were being bred to this particular bull and conceived before this "accidental" breeding took place.

It would appear from the above data that the proportion of beef cows becoming pregnant might be increased if: (1) the interval

TABLE 6. REPRODUCTIVE PERFOMANCE OF COWS SUCKLING CALVES

Station and breeding group	Age		Diagnosed pregnant	Bred 1st 21 days	Not showing heat	Interval from calving to 1st heat: more than 100 days	Interval from calving to 1st heat: more than 90 days	Interval from calving to 1st heat: more than 80 days	Conceived 1st service
	Yr.	No.	%	%	%	%	%	%	%
Front Royal[a]									
Angus	2 and 3	49	88	73	2	4	6	12	58
	4 and older	174	95	84	0	5	9	10	78
Hereford	2 and 3	50	70	62	10	14	18	26	64
	4 and older	152	90	66	1	10	14	20	67
Shorthorn	3	28	89	61	3	28	32	32	74
	4 and older	159	86	65	0.6	8	15	19	63
Iberia[b]									
Brahman-Angus	3 and 4	41	61	37	12	17	23	37	47
	5 and older	46	76	74	2	2	9	13	51
Africander-Angus	3 and 4	13	69	62	15	15	15	15	82
	5 and older	21	100	86	0	10	10	14	67

[a] 1956 and 1957 data.
[b] 1956 data only.

TABLE 7. EFFECT OF *VIBRIO FETUS* ON CONCEPTION RATE

Breed	Herds infected with *Vibrio fetus*				Non-infected herds			
			Services per conception				Services per conception	
	Pregnant		All cows	Cows which conceived	Pregnant		All cows	Cows which conceived
	No.	%	Av. no.	Av. no.	No.	%	Av. no.	Av. no.
Angus	50	64	3.50	2.09	284	93	1.49	1.34
Shorthorn	35	54	3.89	1.63	311	84	1.76	1.38

from calving to first estrus were shortened so that all cows had an opportunity to be bred two or more times during the breeding season, (2) methods were developed for determining and removing from the herd cows of potentially low fertility, and (3) herds were kept free of *Vibrio fetus*.

Summary

Some factors related to failure to conceive and to pre- and post-natal calf losses were studied in Angus, Hereford, and Shorthorn cattle at the Beef Cattle Research Station, Front Royal, Virginia, and in Brahman, Brahman-Angus and Africander-Angus cattle at the Iberia Livestock Station, Jeanerette, Louisiana, in 1956 and 1957. The largest losses in potential calf crop were the result of: (1) failure to conceive or early embryonic death before the first pregnancy check, and (2) death of the calf at or shortly after the time of birth. The proportion of cows conceiving could be increased by: (1) shortening the interval from calving to first estrus, (2) increasing the proportion conceiving at first service, and (3) keeping herds free from *Vibrio fetus*. The interval from calving to first estrus in cows suckling calves was longer in the younger than in the older cows and shorter in the Angus than in the other breeds studied. The conception rate at first service and for the entire breeding season were lower when yearling bulls were used (all breeds except Brahman), in herds having *Vibrio fetus* and in dry cows (exceptions were Africander-Angus and Brahman). Losses at or shortly after birth were quite variable between breeds and years.

Literature Cited

Baker, A. L. and J. R. Quesenberry. 1944. Fertility of range beef cattle. J. Animal Sci. 3:78.

Bryner, J. H. and A. H. Frank. 1955. Laboratory techniques for isolation and propagation of *vibrio* from cattle. Am. J. Vet. Res. 16:634.

Burke, L. R. 1954. Effect of age on reproduction in beef cattle. Proc. Am. Soc. An. Prod. Western Section 5:249.

Ensminger, M. E., M. W. Galgon and W. L. Slocum. 1955. Problems and practices of American cattlemen. Wash. Agr. Exp. Sta. Bul. 562.

Frank, A. H., J. H. Bryner and B. Caruthers. 1958. A comparison of the effect of catalase-positive and catalase-negative *vibrio* on the fertility of cattle. Am. J. Vet. Res. 19:108.

Lasley, J. F. and R. Bogart. 1943. Some factors influencing reproductive efficiency of range cattle under artificial and natural breeding conditions. Mo. Agr. Exp. Sta. Res. Bul. 376.

Lindley, C. E., G. T. Hasley, J. A. Whatley, Jr. and D. Chambers. 1958. A study of reproductive performance of a purebred Hereford herd. J. Animal Sci. 17:336.

McCormick, W. C., B. L. Southwell and E. J. Warwick. 1956. Factors affecting performance in herds of purebred and grade Hereford cattle. Ga. Agr. Exp. Sta. Tech. Bul. N.S. 5.

Warnick, A. C. 1955. Factors associated with the interval from parturition to first estrus in beef cattle. J. Animal Sci. 14:1003.

Wiltbank, J. N., M. J. Burris and B. M. Priode. 1956. The occurrence of estrus and conception in a herd of 450 beef cows bred during a limited breeding season. J. Animal Sci. 15:1216 (Abstr.).

Woodward, R. R. and R. T. Clark. 1959. A study of stillbirths in a herd of range cattle. J. Animal Sci. 18:85.

RATE OF PASSAGE OF FEEDS THROUGH THE DIGESTIVE TRACT OF HOLSTEIN COWS [1]

P. R. SHELLENBERGER [2] AND E. M. KESLER [3]

Pennsylvania State University, University Park

STUDY of the rate of passage of feedstuffs through the digestive system of the ruminant is complicated by the complex nature of the anterior portion of the tract. Cows producing large quantities of milk, as in early lactation, usually excrete feces which are more fluid in consistency than when they are not lactating heavily. At the same time, they consume more feed and water. It appears possible that these factors may result in a more rapid passage of feedstuffs through the digestive tract, with a resultant influence on utilization of feed. The physical nature of the diet has been shown to affect the rate of passage (Ewing and Smith, 1917; Balch, 1950; Balch *et al.*, 1954; Blaxter *et al.*, 1956; Castle, 1956b; King and Moore, 1957; Rodrique and Allen, 1960). Level of feed intake appeared to exert an influence, but not frequency of feeding (Blaxter *et al.*, 1956; Castle, 1956b; Rakes *et al.*, 1957).

Recently, several methods of calculating rate of passage have been proposed (Balch, 1950; Castle, 1956a; Blaxter *et al.*, 1956; Brandt and Thacker, 1958). All are based on staining a portion of the diet and noting appearance of stained particles in the feces. The present investigation constituted a comparison of the proposed methods when applied to dairy cows which were producing milk at relatively high or low levels.

Experimental Procedure

Twelve Holstein cows were used in two trials to study the relationship between level of milk production and the passage of feedstuffs through the digestive system. In the first trial four cows were used in two phases of a crossover type experiment, table 1. During the first phase two of the animals (numbers 927 and 888) were in early lactation and were producing over 50 lb. of milk daily while the remaining two (925 and 933) were in late lactation and producing less than 25 lb. When the second phase of the crossover was initiated, 5 months later, 925 and 933 had started new lactations and were at maximum production, while 927 and 888 were at the end of their lactations. Trial II involved eight different cows, two of high and two of low production in each of two phases. Details on cows used and average feed intakes are presented in table 1.

All cows were housed in a ventilated stanchion barn and adequate straw bedding was provided. Medium quality alfalfa hay and corn silage were fed as the roughage portion of the ration at the rate of 1.5 lb. of hay and 2.5 lb. of silage per 100 lb. body weight. A normal herd concentrate mixture was fed at the rate of 1 lb. per 3.5 lb. of milk produced. The amounts of feed offered during the trial were calculated on the basis of body weight and milk production during the 5 days preceding the preliminary period. All feeds were offered to the cows in two equal portions daily; there were very few refusals.

Measurement of the rate of passage was made during a 10-day collection period which followed a 10-day preliminary period. Calculated intakes of feed for each cow were constant throughout the 20 days. Feces were collected by means of a collection apparatus patterned after that developed by Gorski *et al.* (1957). At a single meal at the beginning of the collection period, each cow was fed a portion of stained hay at the rate of 4% of her daily dry matter intake. The hay was stained by steeping for 6 hours in a hot solution of crystal violet, after which it was rinsed thoroughly with cold water, and dried (Balch, 1950). One-half hour was allowed for eating the stained hay and the mid-point of this half-hour period was used as the "time of feeding". Collection of feces began at this time. The first sampling of feces for stained particles was done 14 hours after "time of feeding". Sampling then was at 6-hour intervals during the next 3 days, at 8-hour in-

[1] Authorized for publication on September 27, 1960, as Paper No. 2493 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

[2] Present address: Department of Dairy Husbandry, Iowa State University, Ames.

[3] Department of Dairy Science.

TABLE 1. AGE, BODY WEIGHT, LEVEL OF MILK PRODUCTION, AND DRY MATTER INTAKE OF HOLSTEIN COWS USED IN RATE-OF-FEED-PASSAGE STUDIES

Trial no.	Phase	Herd no. of cow	Age	Body weight	Average daily milk production during trial	Average daily dry matter intake during trial
			yr.–mo.	lb.	lb.	lb.
I	A	927	4–6	1490	64.5	42.5
		888	7–0	1365	60.2	44.0
		925	4–6	1190	24.0	31.7
		933	4–3	1190	22.6	32.4
	B	927	4–11	1475	23.0	36.6
		888	7–5	1410	2.8	32.5
		925	4–11	1175	46.7	38.4
		933	4–8	1285	53.8	38.4
II	A	938	4–8	1100	50.2	34.9
		930	5–2	1445	59.8	43.9
		923	5–4	1405	25.7	35.2
		931	5–2	1285	23.8	32.1
	B	958	3–8	1135	55.2	37.9
		952	4–2	1175	73.8	42.4
		969	3–1	1100	25.9	28.8
		967	3–2	1390	26.9	34.4

tervals for the following 3 days, at 12-hour intervals during the 7th and 8th days, and at 18-hour intervals during the last 2 days. When necessary, the feces collection bag was emptied one or more times during the interval, the feces being stored in cans. At each time of sampling the feces which had accumulated during the interval were mixed thoroughly and weighed. A representative sample was obtained and the remainder of the feces was discarded. The sample was stored at 3° C. and subsequently used for making up the composite sample and as a source of feces for counting the number of stained particles. A composite sample for each cow was made for the duration of the experimental period at the rate of 15 gm. per kg. of feces voided. Composite samples were frozen and stored at −15° C.

Stained particles were counted in each of three 2.5 gm. portions of the feces obtained at each sampling period. The portions were weighed into small beakers, transferred onto a double-thickness cheesecloth disk which was stretched inside the top of a cylindrical washing apparatus (5 in., inside diameter). The apparatus permitted a flow of 5.25 l. of water per minute.

After 1 minute of washing, the cloth and remaining fecal residue were removed from the apparatus, placed on a paper towel and allowed to dry. Stained particles remaining on the gauze were counted and recorded as the number of particles per gram of dry matter in the feces. The number of particles per sampling period was calculated and each period total was expressed as a percentage of the total number of particles excreted during the 240-hour experimental period. Accumulative percentages were plotted against time and the "5%" and "80–5% excretion times" (Balch, 1950) were determined from the resulting sigmoid-shaped curve. Balch (1950) developed the concept of the "5% excretion time" as being a measure of the time required for food residues to traverse the omasum, abomasum and intestines; and the "80–5% excretion time" as time required for passage through the rumen and reticulum. Castle (1956a) calculated a value termed "R" which was defined as the mean retention time of colored particles in the digestive tract. This was done by summing the times of excretion between 5 and 95%, at 10% intervals taken from the graph, and averaging. Blaxter *et al.* (1956) reported passage rate in terms of "mean time", the sum of times which individual stained particles spent in the tract divided by the number of stained particles excreted. Brandt and Thacker (1958) calculated "t_1" and "t_2" which were to replace the measures used by Balch (1950). In the present study the stained particle counts were used to calculate rate of passage by each of the above mentioned methods.

During the preliminary and experimental

periods all feeds were sampled at frequent intervals and composited. Composites were stored in air-tight containers until the end of the experimental period. Corn silage samples were frozen and stored at —15° C. The hay and concentrate samples were ground in a Wiley Mill, using the medium sieve. All samples, including the thawed silage samples, were mixed thoroughly and the dry matter content of each was determined by drying at 100° C. in a Brabender semi-automatic moisture tester. The average daily dry matter intake of each cow was calculated from the weight of each feed as fed and its average dry matter content, table 1.

The dry matter content of the feces was determined during Trial I by drying three 200 gm. portions of each composite sample in an electric oven at 100° C. until a constant weight was obtained. In Trial II a Brabender semi-automatic moisture tester was used, and five 10-gm. samples of each feces composite were dried at 100° C. until a constant weight was reached, usually about 4 hours.

Results and Discussion

Inspection of the data revealed no differences in results obtained in Trials I and II, therefore they have been combined, table 2. The data indicate, regardless of criterion used, that the rate of passage was somewhat faster in the high production group than in the low. Statistical analysis indicated, however, that only rate of passage as measured by "R", "mean time" and "t_2" were significantly faster in the high production group. The first particles of dyed hay appeared in the fecal samples collected at 14 to 20 hours after feeding. Most of the particles were excreted during the period between 26 and 120 hours after feeding; very few appeared after 160 hours.

The values for rate of passage observed in this study compare favorably with those reported by other workers (Balch, 1950; and Brandt and Thacker, 1958). A relationship appeared to exist between the various measures of rate of passage in that they fluctuated as a group. Theoretically, the "5% excretion time" and "t_1" should measure time spent by the residues passing through the omasum, abomasum and intestines of the animal. In this study these two measures were insignificantly correlated ($r=-.04$). The "80–5% excretion time" and "t_2" values, theoretically measures of time spent by the feedstuff in the reticulo-rumen, were highly correlated ($r=0.88$). The "R" and "mean time" values are both measures of the mean time spent by each stained particle in the digestive tract, both were similar numerically and the standard deviations of both were low. It appears, therefore, that either might be used to further examine factors affecting rate of passage. Rate of passage, measured in terms of "R" values, was significantly correlated with average daily milk production ($r=-.62$; $P<0.05$). Since cows at high production received more feed, the relationship between level of feed intake and rate of passage was studied. Average daily dry matter intake, expressed as gm. per kg. body weight, was significantly correlated with "R" values ($r=-.66$; $P<0.01$).

Apparent digestion of dry matter during the 10-day feces collection period was calculated for each cow. The eight cows in high production averaged 65.6±0.42% digestion

TABLE 2. RATE OF PASSAGE OF FEEDS THROUGH COWS OF HIGH AND LOW PRODUCTION [a]

	Measures of rate of passage (in hours)					
	Excretion times					
Production level	5%	80–5%	R	Mean time	t_1	t_2
High	20.9 ±4.8[b]	54.6 ±8.0	51.9** ±7.9	53.5* ±8.8	9.5 ±4.9	21.4* ±3.7
Low	26.2 ±7.0	59.5 ±8.3	63.2 ±6.6	62.8 ±6.0	9.9 ±4.1	26.2 ±4.7
Difference	5.3	4.9	11.3	9.3	0.4	4.8

[a] Values are means of eight observations.
[b] Standard deviation from the mean.
* Significantly faster than low production ($P<0.05$).
** Significantly faster than low production ($P<0.025$).

of dry matter, while those in low production averaged 65.8±1.01. Thus it is apparent that no differences existed between the groups, and that digestibility of dry matter was not influenced by rate of passage.

Summary

Twelve Holstein cows were used to study rate of passage of feedstuffs through the digestive system. Four of the twelve were used twice in a crossover design, each being tested when milking at relatively high and low levels. Eight additional animals, four each of high and of low production, were used once in a group comparison. All cows were fed normal herd rations according to size and production. Rate of passage was determined by feeding a meal of stained hay and observing appearance of stained particles in the feces. Total fecal collections were made and feed intake was held constant during the experiment. Rate of passage was faster in those cows producing milk at the higher levels, and consuming greater quantities of feed and water, although the magnitude of the differences was not great. Level of dry matter intake was significantly correlated with rate of passage. Several previously suggested methods of calculating passage rate were employed; all appeared satisfactory, but those measuring the mean time spent by each stained particle in the digestive tract appeared to be slightly more reliable. Dry matter digestibility averaged 65.7% and was not different between cows of high and low production.

Literature Cited

Balch, C. C. 1950. Factors affecting the utilization of food by dairy cows. 1. The rate of passage of food through the digestive tract. British J. Nutr. 4:361.

Balch, C. C., D. A. Balch, S. Bartlett, V. W. Johnson, S. J. Rowland and Jill Turner. 1954. Studies of the secretion of milk of low fat content by cows on diets low in hay and high in concentrates. IV. The effect of variations in the intake of digestible nutrients. J. Dairy Res. 21:305.

Blaxter, K. L., N. McC. Graham and F. W. Wainman. 1956. Some observations on the digestibility of food by sheep, and on related problems. British J. Nutr. 10:69.

Brandt, C. S. and E. J. Thacker. 1958. A concept of rate of food passage through the gastro-intestinal tract. J. Animal Sci. 17:218.

Castle, Elizabeth J. 1956a. The rate of passage of foodstuffs through the alimentary tract of the goat. 1. Studies on adult animals fed on hay and concentrates. British J. Nutr. 10:15.

Castle, Elizabeth J. 1956b. The rate of passage of foodstuffs through the alimentary tract of the goat. 2. Studies on growing kids. British J. Nutr. 10:115.

Ewing, P. V. and F. H. Smith. 1917. A study of the rate of passage of food residues through the steer and its influence on digestion coefficients. J. Agr. Res. 10:55.

Gorski, J., T. H. Blosser, F. R. Murdock, A. S. Hodgson, B. K. Soni and R. E. Erb. 1957. A urine and feces collecting apparatus for heifers and cows. J. Animal Sci. 16:100.

King, K. W. and W. E. C. Moore. 1957. Density and size as factors affecting passage rate of ingesta in the bovine and human digestive tracts. J. Dairy Sci. 40:528.

Rakes, A. H., W. A. Hardison, J. Albert, W. E. C. Moore and G. C. Graf. 1957. Response of growing dairy heifers to frequency of feeding. J. Dairy Sci. 40:1621.

Rodrique, C. B. and N. N. Allen. 1960. The effect of fine grinding of hay on ration digestibility, rate of passage, and fat content of milk. Canad. J. Animal Sci. 40:23.

INFLUENCE OF EARLY WEANING ON CREEP-FED MILK LAMBS WHEN WEANED ON WEIGHT OR AGE

DON G. BROTHERS AND J. V. WHITEMAN

Oklahoma Agricultural Experiment Station,[1] *Stillwater*

WEANING spring lambs prior to market weight will permit more efficient use of good pasture by reserving it for growing lambs. Ewes can be moved to a lower quality pasture and wintered cheaply. This production system will also simplify management and afford a longer period of recovery for ewes before the next breeding season begins. Various workers have reported little effect on rate of gain of lambs due to early weaning. Barnicoat *et al.* (1949, 1956) found that ewes produce very little milk by the time the lamb is 9 to 12 weeks old, and correlations between milk consumed and gain of the lamb after 7 weeks were low. These and other reports concerning the lactation pattern of ewes indicate why early weaning may be desirable.

This paper reports the results of a study designed to determine the effect of early weaning on subsequent gain and market grade of spring lambs. An attempt was also made to find the minimum age and/or weight when early weaning may be done without detrimental effects ensuing.

Materials and Methods

The lambs used in this experiment were born during the late falls of 1958 and 1959. The dams of these lambs were western ewes purchased from Texas and New Mexico and Dorset-western crossbred ewes saved from the Oklahoma Agricultural Experiment Station flock at Ft. Reno as replacements in previous seasons. Hampshire and Suffolk sires were used in 1958 and Hampshire, Suffolk and Dorset sires were used in 1959. All the rams were purchased from purebred breeders in Oklahoma.

When the lambs were approximately 1 week old, the ewes and lambs were moved to a wheat pasture. The lambs were creep-fed, free choice, a mixture of two parts cracked milo and one part chopped alfalfa hay of good quality. Individual weighing of the lambs began in late November or early December, when the older lambs were approximately 1 to 2 months old, and continued throughout the season at 2-week intervals.

In the 1958–59 season part of the lambs were from yearling ewes and part were from 2-year old ewes. One-half of the single lambs in each of these age groups was weaned when they reached a minimum weight of 50 lbs. and one-half was left with their dams. Fourteen sets of twin lambs were also available from these ewes. One member of each twin-pair was weaned and the other member was left with its dam. The sex of the lamb and breed of the ewe were also considered when determining whether or not a lamb would be weaned, so that approximately equal numbers of both sexes from each breed were weaned.

In the 1959–60 season, single lambs only were weaned at a minimum age of 56 days rather than at a minimum weight. Since Dorset sires were also used during this season face color and sex of the lamb were the principal criteria for determining which lambs were to be weaned. One-half of the lambs of each sex within each face color was weaned and one-half was not. The dams of these lambs were yearling, 2 year old and 3 year old ewes. One-half of the lambs from each group of ewes was weaned and one-half was not.

Lambs were given an estimated live grade and marketed when they reached a minimum weight of 90 lb. The lambs usually reached this weight between early and late spring during both seasons. All weaning and marketing occurred on regular weighing days.

Results and Discussion

The results of the 1958–59 trial are contained in table 1 and the analyses of variance for this trial are presented in tables 2 and 3. Average daily gains were computed for the first 2 weeks of the post-weaning period,

[1] In cooperation with Animal Husbandry Research Division, A.R.S., U.S.D.A.

TABLE 1. AVERAGE DAILY GAIN OF WEANED AND NON-WEANED LAMBS DURING FIRST TWO WEEKS OF THE POST-WEANING PERIOD, TWO WEEKS POST-WEANING TO FINAL WEIGHT AND FOR THE ENTIRE PERIOD (1958–59)

Weaning group	Number of lambs	Average weaning age*	Average weaning weight*	Average daily gain first two weeks	Average daily gain two weeks to final	Average daily gain entire period
		days	lb.	lb.	lb.	lb.
Single lambs (yrlg. dams)						
Weaned	23	78	55	0.48	0.51	0.50
Non-weaned	21	74	53	0.63	0.51	0.53
Single lambs (2-year old dams)						
Weaned	24	69	56	0.46	0.57	0.54
Non-weaned	25	69	55	0.50	0.60	0.57
All single lambs						
Weaned	47	73	55	0.47	0.54	0.52
Non-weaned	46	71	54	0.56	0.56	0.55
Twin pairs						
Weaned	14	86	52	0.57	0.56	0.56
Non-weaned	14	83	54	0.52	0.62	0.60
All lambs						
Weaned	61	76	55	0.49	0.54	0.53
Non-weaned	60	74	54	0.55	0.57	0.56

* For the non-weaned lambs, these figures are the ages and weights at the time the weaned lambs were weaned.

TABLE 2. ANALYSES OF VARIANCE COMPUTED FROM SINGLE LAMB DATA (1958–59)

Source	d.f.	Mean squares		
		First 2 wks.	2 wks.–final	Entire period
Total	92			
Age of dam	1	0.1028	0.1155***	0.0460**
Sex	1	0.0663	0.1056***	0.0845***
Weaning	1	0.1928*	0.0064	0.0190
Age x sex	1	0.0883	0.0693**	0.0262
Age x weaning	1	0.0857	0.0047	—0.0020
Sex x weaning	1	0.1835*	0.0188	0.0257
Error	86	0.0550	0.0142	0.0105

* $P<.10$.
** $P<.05$.
*** $P<.01$.

TABLE 3. ANALYSES OF VARIANCE COMPUTED FROM TWIN LAMB DATA (1958–59)

Source	d.f.	Mean squares		
		First 2 wks.	2 wks.–final	Entire period
Total	27			
Sex	1	0.0067	0.0384*	0.0156
Weaning	1	0.0155	0.0252	0.0093
Sex x weaning	1	0.0001	0.0158	0.0069
Error	24	0.0636	0.0125	0.0084

* $P<.10$.

from 2 weeks post-weaning to final weight and for the entire post-weaning period. For the non-weaned lambs, the first 2 weeks of the post-weaning period corresponds in time to the same period for the weaned lambs; however, the other two post-weaning periods do not completely correspond in time because the weaned lambs reached market weight slightly later than the non-weaned lambs.

All single lambs weaned and non-weaned gained an average of 0.47 and 0.56 lb. per day, respectively, during the first 2 weeks of the post-weaning period (table 1). This adverse effect due to weaning may be real ($P<.10$) as indicated in table 2. However, the effect on growth rate due to weaning single lambs was negligible during the period from 2 weeks post-weaning to market (0.54 vs. 0.56) and over the entire period (0.52 vs. 0.55). The weaned member of each pair of twins had a superior rate of gain during the first 2 weeks of the post-weaning period, but this growth pattern was not maintained throughout the trial and little difference due to weaning was evident when average daily gain for the entire trial period was examined. No significant difference (table 3) was found due to weaning during any of the growth periods. The results (table 1) for all lambs show little difference in average daily gain between weaned and non-weaned lambs (0.53 vs. 0.56) during the entire period. The greatest influence due to weaning was manifest during the first 2-week period; however, statistical analyses of the total data showed no significant difference due to weaning in any of the growth periods investigated.

For the single lambs, the decrease in gain during the first 2 weeks of the post-weaning period indicates that any shock due to weaning may cause growth rate of lambs to subside for a short period of time until an adjustment to a new environment can be made. Jordan *et al.* (1959) noted that lambs weaned at 10 weeks of age and fed in dry-lot had a low feed consumption during the first 2 weeks and virtually no gain was made; however, their gain from 2 weeks post-weaning was slightly faster than non-weaned lambs. Lambs weaned at 12 and 13 weeks of age and fed in dry-lot made slightly faster gains than non-weaned lambs. These data indicated that lambs weaned at 10 weeks of age were not sufficiently mature to withstand the shock of weaning but 12 and 13-week old lambs were. It can be noted in table 1 that the twin lambs were about 12 weeks old at weaning. This may partially explain why they were not adversely affected during the first 2 weeks of the post-weaning period as were the single lambs which were only slightly over 10 weeks old.

Table 2 reveals sources of variation other than weaning which had a significant effect on single-lamb rate of gain. Lambs from 2-year-old ewes gained faster than lambs from yearling ewes and wethers gained faster than ewe lambs from 2 weeks post-weaning to final weight and for the entire trial period from weaning to final weight. Both these effects have been noted previously in the literature. A significant age-of-ewe x sex interaction for the period from 2 weeks post-weaning to final weight indicated that wether and ewe lambs from yearling dams had about the same rate

TABLE 4. AVERAGE DAILY GAIN OF WEANED AND NON-WEANED LAMBS DURING FIRST TWO WEEKS OF THE POST-WEANING PERIOD, TWO WEEKS POST-WEANING TO FINAL WEIGHT AND FOR THE ENTIRE PERIOD (1959–60)

Face color and weaning group of lamb	Number of lambs	Average weaning age	Average weaning weight	Average daily gain first two weeks	Average daily gain two weeks to final	Average daily gain entire period
		days	lb.	lb.	lb.	lb.
Black faced						
Weaned	34	62	47	0.36	0.50	0.48
Non-weaned	35	61	49	0.51	0.56	0.54
White faced						
Weaned	18	60	45	0.34	0.47	0.45
Non-weaned	17	61	48	0.38	0.52	0.49
Total						
Weaned	52	61	46	0.35	0.48	0.47
Non-weaned	52	61	48	0.47	0.54	0.52

TABLE 5. ANALYSES OF VARIANCE COMPUTED FROM THE DATA (1959–60)

Source	d.f.	Mean squares		
		First 2 wks.	2 wks.–final	Entire period
Total	103			
Face color	1	0.1272*	0.268	0.0369*
Sex	1	0.0038	0.0567*	0.0379*
Age of dam	2	0.0749	0.0167	0.0065
Weaning	1	0.3509***	0.0912**	0.0872***
Face x sex	1	0.0772	0.0153	0.0067
Face x age	2	—0.0321	0.0065	0.0012
Face x weaning	1	0.0576	—0.0019	0.0009
Sex x age	2	0.0840	0.0106	0.0028
Sex x weaning	1	0.0261	0.0059	0.0070
Age x weaning	2	0.0427	0.0343	0.0232
Error	89	0.0407	0.0167	0.0105

* $P<.10$.
** $P<.025$.
*** $P<.005$.

of gain, but wether lambs out-gained ewe lambs when both were from 2 year old dams. A sex x weaning interaction ($P<.10$) during the first 2-week growth period indicates that weaning had a marked influence on wether lambs but little influence on growth of ewe lambs during this early period. The only significant difference ($P<.10$) in the twin lamb data noted in table 3 was due to sex. When both single and twin lambs were grouped for analysis the interaction of birth type with weaning was significant in all three growth periods. Other interactions also resulted or became more highly significant.

The results of the trial conducted during the 1959–60 season are contained in table 4 and the analyses of variance for this trial are recorded in table 5. Weaning significantly reduced the average daily gain of all lambs weaned during the three growth periods studied. This reduction in growth rate was again greatest during the first 2 weeks of the post-weaning period (0.35 vs. 0.47 lb.) with the subsequent rate of growth from 2 weeks after weaning to market being less severe (0.48 vs. 0.54 lb.). These lambs were slightly over 8½ weeks old at weaning and consequently may have been too immature to withstand the shock due to weaning as previously noted by Jordan *et al.* (1959).

Table 5 also indicates that genetic differences associated with face color of the lamb may have caused a real difference ($P<.10$) in average daily gain during the first 2 weeks after weaning and for the entire period. Black-faced lambs gained faster during these two periods than did the white-faced lambs. Wethers also gained faster than ewe lambs ($P<.10$) during the 2-week post-weaning to final weight period and for the entire trial period.

Although age of ewe was not considered an important factor in allotting the lambs to treatment, it was removed as a source of variation since it was found to be significant during the 1958–59 trial. However, no significant difference in growth of lambs due to age of ewe was found in this second trial. All first order interactions, in each of the two trials, were removed since it was not known which interactions, if any, would be significant.

Table 6 contains the average estimated live grades of weaned and non-weaned lambs during both seasons of this study. These results indicate practically no influence on subsequent grade of lambs due to weaning. Although weaning may retard lamb growth rate so that market weight is reached at a later date, it appears that once this weight is reached the market grade of the lamb is unchanged. These results are in fair agreement with findings by Baird and Sell (1959) who checked market grade in two trials. In the

TABLE 6. AVERAGE ESTIMATED LIVE GRADES OF LAMBS WEANED AND NON-WEANED

Year and treatment	Number of lambs	Average estimated live market grades[a]
1958–59		
Weaned	61	12.03
Non-weaned	60	12.52
1959–60		
Weaned	52	12.73
Non-weaned	52	12.79

[a] 12=High choice.
13=Low prime.

first trial, lambs weaned at 60 lb. had a superior slaughter grade to lambs not weaned prior to market weight; however, in the second trial their results indicated no slaughter grade differences due to early weaning.

In both years of this study early weaned lambs did not gain as fast after weaning as the non-weaned lambs, although not all these differences in average daily gain were significant. The adverse effect due to weaning was not as great in the 1958–59 season, when lambs were weaned at a minimum weight, as in the 1959–60 season when weaning was at a minimum age. This was expected because in the first trial average weaning weight and average weaning age at the trial's beginning were approximately 55 lb. and 76 days, respectively. However, in the second trial the average weight and age at weaning were approximately 46 lb. and 61 days, respectively. Jordan *et al.* (1959) found that weaning at 10 to 13 weeks of age (70–91 days) had no detrimental effect on subsequent rate of gain. However, weaning at 8–10 weeks of age (56–70 days) in some cases reduced subsequent gain. This is in fairly close agreement with the results obtained from this experiment.

Baird and Sell (1959) weaned lambs early (45 and 60 lb.) and found no significant differences in average daily gain when compared with lambs weaned at market weight. Barnicoat *et al.* (1956) weaned lambs at 9, 12, and 16 weeks of age and found no difference in rate of gain from birth to 20 weeks of age. Single lambs weaned at 9 weeks of age were slowed in early post-weaning growth rate but recovered to show no final disadvantage. These reports do not agree completely with the results of the 1959–60 season in this study when lambs, weaned at about 46 lb. and 61 days of age, did not gain to market weight as fast as did lambs that were not weaned.

In both years of this study the pasture supply became limited during late January when many of the lambs were being weaned. It was felt that this lack of pasture would adversely effect the weaned lambs more than those that were left with their dams. Also, due to the pasture facilities available, ewes and lambs were run together and weaning consisted of removing the ewes from the pasture and leaving the weaned lambs with non-weaned lambs and their dams. This may have caused more stress on weaned lambs directly after the weaning period than if only weaned lambs were run together because the weaned lambs may have spent considerable time looking for their dams in the pasture where other ewes were kept.

In the first season of this study (table 1) when lambs were randomly weaned on weight, the weaned and non-weaned lambs weighed approximately the same (55 vs. 54 lb.). However, the lambs weaned were about 2 days older (76 vs. 74 days) than lambs not weaned and, consequently, slower gaining lambs were weaned. A small non-significant negative correlation between weaning age and average daily gain was found during the first 2 weeks after weaning, but the negative correlation was significant ($P<.05$) for the entire growth period. In the second season of this study lambs were weaned at an age which was equal (61 days) for weaned and non-weaned lambs (table 4). Yet the weaning weight was less (46 vs. 48 lb.) for the lambs weaned than for the lambs not weaned, and the slower gaining lambs were again weaned due to random error. A small non-significant positive correlation was found between weaning weight and average daily gain after weaning during the first 2 weeks after weaning but a significant positive correlation ($P<.01$) was found for the entire period. These correlations indicate that the youngest lambs at weaning, when weaning was at about 50 lb. gained faster to market than older lambs weaned at this weight. Also, when a minimum age of 56 days was the basis for weaning, light lambs which reached the minimum age did not gain as fast in the post-weaning period as heavier lambs that had gained faster up to weaning. Therefore, it appears that the random error committed in this experiment of weaning the slowest gaining lambs may have had some influence on their failure to gain as rapidly post-weaning as non-weaned lambs.

Further investigation of the results of both trials revealed that the rate of gain of single lambs weaned at about 50 lb. was not appreciably affected if they were at least 70 days old at weaning. However, all single lambs younger than 70 days were apparently too young to wean without affecting their subsequent gain regardless of their weight. Twin lambs, which were older than 70 days when they reached approximately 50 lb. showed little effect due to weaning. Therefore, the results of this study indicate that single lambs on wheat pasture and good creep feed may be weaned when they reach an approximate

minimum weight of 50 lb. and are at least 70 days old without influencing their subsequent gain or market grade. Twin lambs of this weight are usually older and may show no significant decrease in gain due to weaning.

Summary

Two separate trials of early weaning creep-fed spring lambs grazing wheat pasture were conducted by the Oklahoma Agricultural Experiment Station from 1958–60. In the 1958–59 season one-half of 121 crossbred single and twin lambs was weaned when they reached a minimum weight of 50 lb., and in the 1959–60 season one-half of 104 crossbred single lambs was weaned when they reached a minimum age of 56 days. Lambs were given an estimated live grade and marketed when they reached a minimum weight of 90 lb.

In the 1958–59 season the average weight at weaning was 55 lb. and the average age was 76 days. Little difference in gain of weaned and non-weaned lambs was found during the entire post-weaning period with the greatest influence due to weaning being manifest in the first 2 weeks of the post-weaning period. In the 1959–60 season the average weight at weaning was 46 lb., and the average age was 61 days. Weaning significantly reduced the post-weaning average daily gain of weaned lambs compared to non-weaned lambs. This reduction in growth rate was again greatest during the first 2 weeks of the post-weaning period. Combined results of both trials suggested that lambs less than 70 days old are too young to wean without influencing their subsequent gain regardless of their weight. However, single lambs weighing about 50 lb. and at least 70 days old were weaned without influencing their subsequent gain. Twin lambs, which were usually older than 70 days when they reached approximately 50 lb., showed no significant decrease in average daily gain due to weaning. Average estimated live grades at marketing appeared not to be influenced by weaning in either year.

Literature Cited

Baird, D. M. and O. E. Sell. 1959. Spring lamb production practices with winter temporary pastures in Georgia. Ga. Agr. Exp. Sta. Bul. N.S. 63.

Barnicoat, C. R., A. G. Logan and A. I. Grant. 1949. Milk-secretion studies with New Zealand Romney ewes. Parts III and IV. J. Agr. Sci. 39:237.

Barnicoat, C. R., P. F. Murray, E. M. Roberts and G. S. Wilson. 1956. Milk-secretion studies with New Zealand Romney ewes. Parts V–XI. J. Agr. Sci. 48:9.

Jordan, R. M., H. E. Hanke and D. Reimer. 1959. The early weaning of lambs. Feedstuffs 31(19):86.

PRODUCTION OF A POPULATION WITH EQUAL FREQUENCY OF GENES FROM THREE PARENTAL SOURCES

EDWIN LAUPRECHT [1, 2]

Max-Planck-Institut, Mariensee, Germany

THE attempt to combine three races or breeds in various proportions must have been made many times in the past. Since the experiments of Russell (1919) with sheep and of Winters *et al.* (1935) with swine, the combining of three different parental types in some predetermined proportion has become a scientific problem in animal breeding. Russell and Winters *et al.* mated individuals from two different parental types, the resulting progeny being mated to a third parental type.

Lush *et al.* (1939) derived the model for carrying this still further, mating sires of three parental breeds in regular rotations to females of each succeeding generation. The authors calculated that with this breeding method the gene frequencies quickly approach an equilibrium in which the individuals get 4/7 of their genes from the breed of their sire, 2/7 from the breed of their dam's sire, and 1/7 from the breed of the sire of their maternal grandam. The consecutive generations of this method are represented graphically by Lauprecht (1957).

The main purpose of such rotation crossing is to maintain a high degree of heterosis. In only 1/7 of the pairs of genes, when in the equilibrium state, will both genes of the pair come from the same breed. That is, 6/7 of the pairs will be "crossbred" and only 1/7 be "purebred", so to speak. This will maintain a high degree of heterosis, so far as heterosis depends on intra-allelic interactions.

One might, however, wish to form a new breed with nearly equal contributions of each of the 3 breeds to the gene pool, but hoping that selection during the process would get in the final product more than 1/3 of the good qualities of each breed which went into it. The procedure would be different.

A procedure of this kind was planned theoretically by Russell (1919). To begin with, he produces the three possible combinations of the three parental types. In the next generation the individuals of these three different combined populations are mated together. The individuals of the three resulting populations then are combined again as in the preceding generation. Russell continues from generation to generation in the same way. A different plan for producing a population of this kind is presented herewith.

Results and Discussion

The first step is to mate individuals of the first parental type (P_0) to those of the second parental type (P_1). Their progeny (C_1) are mated to animals of the third parental type (P_2) as was done by the authors already cited. In the resulting offspring (C_2) the probable gene contributions from the three parental types are: 25% P_0+25% P_1+50% P_2. The principle to be followed in the next generation is to mate them so as to keep the gene frequency of P_0 and P_1 equal but to reduce the frequency of P_2 from 50% toward 33%.

To accomplish this the females of population C_2 are mated to the males of their parental population, C_1. The offspring are population C_3. The females of this population are mated to males of C_2. This principle of mating is continued as shown in table 1.

It should be pointed out, as can be seen from table 1, that from the third offspring population (C_3) the sex has to be specified

TABLE 1. THE POPULATIONS OF PARENTS (P) AND PROGENY (C), IN SUCCESSIVE GENERATIONS, USED TO PRODUCE BREEDING STOCK IN WHICH THE GENES OF THE THREE HOMOZYGOUS PARENTAL TYPES (P_0, P_1 AND P_2) ARE EXISTING WITH APPROXIMATELY EQUAL FREQUENCY

Maternal population	×	Paternal population	=	Progeny population
P_0		P_1		C_1
C_1		P_2		C_2
C_2		C_1		C_3
C_3		C_2		C_4
C_4		C_3		C_5
C_5		C_4		C_6

[1] Guest Professor in the Autumn of 1958 at the Department of Animal Husbandry, Iowa State University, Ames, Ia.

[2] The author wishes to thank Professor Jay L. Lush, Ames, Iowa, for his help. He is indebted also to Dr. Edward Walter, Mariensee.

TABLE 2. PROBABLE FRACTIONS OF GENES FROM EACH OF THE THREE PARENTAL TYPES (P_0, P_1, AND P_2) IN SUCCESSIVE PROGENY POPULATIONS

Generation	Fractions			Percent[a]			Departure from 33.3%[a]		
	P_0	P_1	P_2	P_0	P_1	P_2	P_0	P_1	P_2
C_1	$\frac{1}{2}$	$\frac{1}{2}$	...	50.0	50.0	....	+16.7	+16.7	....
C_2	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{2}{4}$	25.0	25.0	50.0	− 8.3	− 8.3	+16.7
C_3	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{2}{8}$	37.5	37.5	25.0	+ 4.2	+ 4.2	− 8.3
C_4	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{6}{16}$	31.3	31.3	37.5	− 2.1	− 2.1	+ 4.2
C_5	$\frac{11}{32}$	$\frac{11}{32}$	$\frac{10}{32}$	34.4	34.4	31.3	+ 1.0	+ 1.0	− 2.1
C_6	$\frac{21}{64}$	$\frac{21}{64}$	$\frac{22}{64}$	32.8	32.8	34.4	− 0.5	− 0.5	+ 1.0
	...	...	...						
	...	...	...						
	...	...	...						
C_n	$\frac{1}{3}-\frac{2}{3}(-\frac{1}{2})^{n+1}$	$\frac{1}{3}-\frac{2}{3}(-\frac{1}{2})^{n+1}$	$\frac{1}{3}+\frac{2}{3}(-\frac{1}{2})^{n}$						

[a] Rounded values.

as was done here. However, this method can also be used if the sexes shown in the parental columns in table 1 are interchanged.

Table 2 shows how much each of the three parental types has contributed to the genetic constitution of the individual progeny populations. Equality of genetic contribution from the three parental types is approached closely after only a few generations.

If we denote the gene portions from P_0, P_1, P_2 in the n^{th} generation with $P_{0,n}$, $P_{1,n}$, $P_{2,n}$, $n \geqslant 3$, the following general equations arise:

$$P_{0,n}=\frac{1}{2}(P_{0,n-1}+P_{0,n-2})$$

$$P_{1,n}=\frac{1}{2}(P_{1,n-1}+P_{1,n-2})$$

$$P_{2,n}=\frac{1}{2}(P_{2,n-1}+P_{2,n-2})$$

with, $P_{0,1}=\frac{1}{2}$ $\quad P_{0,2}=\frac{1}{4}$

$P_{1,1}=\frac{1}{2}$ $\quad P_{1,2}=\frac{1}{4}$

$P_{2,1}=0$ $\quad P_{2,2}=\frac{1}{2}$

From this follows (Kempthorne, 1957, p. 35):

$$P_{0,n}=P_{1,n}=\frac{1}{3}+\frac{2}{3}(-\frac{1}{2})^{(n+1)}$$

$$P_{2,n}=\frac{1}{3}+\frac{2}{3}(-\frac{1}{2})^{n} \quad \text{for all } n\geqslant 1$$

The fractions approach 1/3 exponentially. The portions of genes from the three homozygous parental types can be shown on a triangle the corners of which are defined by the three parental types P_0, P_1, and P_2 (figure 1).

With rotational crossing of three homozygous parental types with their progeny, the expected gene percentages within each generation approach the three corners of the small dashed triangle in figure 1, which contains 1/7 of the total area of the large triangle.

The method which is presented here deviates considerably from the rotational situation because the gene portions of P_0 and P_1 are equal in each generation thus giving a straight line. The composition of the gene pool (neglecting the deviations which selection would make) is shown in figure 1 for the successive generations C_1, C_2, . . . M.

For applying this method it is recommended that the number of individuals in each generation, especially the number of sires, be kept as high as possible to avoid the undesirable effects of inbreeding. Also, of course, strong selection is necessary to achieve the greatest success within the limits of this mating system.

Russell's procedure requires three different populations in each generation in opposition to our method which needs no more than one population in each generation, therefore giving a better possibility for selection. Yet the desired portion of genes is approached at the same rate, as may be seen in page 9 of Russell's paper in table 2 of the present article.

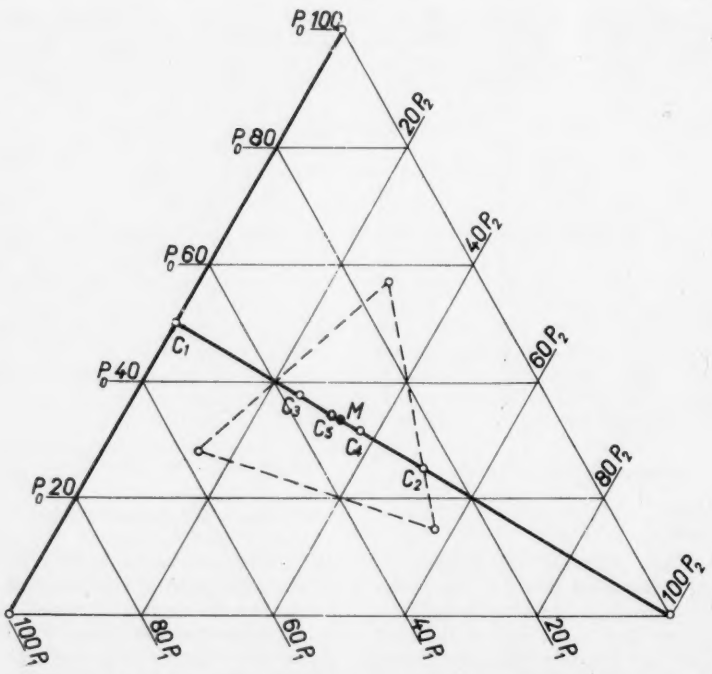


Figure 1. The corners of the triangle indicate the three parental types P_0, P_1, and P_2. The figures on the three sides of the triangle give the probable percentages of genes from each of these three parental types. For instance, point C_2 indicates that this generation has 50% of its genes from P_0 and and 50% from P_1, but none from P_2. Generation C_5, on the other hand, would probably get 37.5% of its genes from P_0, 37.5% from P_1 and 25% from P_2. M is the center point where 1/3 of the genes would have come from each of the three breeds.

The corners of the broken-line triangle indicate the compositions (1/7, 2/7 and 4/7) of successive generations when a regular 3-breed rotation has reached its equilibrium state. The rotation system maintains more heterozygosis than the C-system,—subsequent to C_3. However, the C-system tends toward a single interbreeding population with an average composition which doesn't change from one generation to the next, except as it is changed by selection or by the genetic drift which can be important in a small population. By contrast, the composition of successive generations continues to change widely under the rotation system, although in a regular way.

Summary

A plan is presented for producing a stock in which the genes of the three parental types occur with approximately equal frequency.

Literature Cited

Kempthorne, O. 1957. An Introduction to Genetic Statistics. John Wiley & Sons, Inc., New York.

Lauprecht, E. 1957. Ein Beitrag zur Darstellung der Zuchtverfahren. Z. Tierzüchtung und Züchtungsbiologie. 70:122.

Lush, J. L., P. S. Shearer and C. C. Culbertson. 1939. Crossbreeding hogs for pork production. Ia. Agr. Exp. Sta. Bul. 380.

Russell, S .F. 1919. Inheritance of characters in sheep. Okla. Agr. Exp. Sta. Bul. 126.

Winters, L. M., O. M. Kiser, P. S. Jordan and W. H. Peters. 1935. A six years study of crossbreeding swine. Minn. Agr. Exp. Sta. Bul. 320.

EFFECT OF LEVULINIC ACID ON DIGESTIBILITY, FATTY ACID PRODUCTION AND MICROBIAL ACTIVITY IN DAIRY HEIFERS AND WETHERS [1]

D. E. WALDERN,[2, 4] W. K. ROBERTS,[3, 5] T. H. BLOSSER [2] AND I. A. DYER [3]

Washington Agricultural Experiment Station, Pullman

WITHIN the past 10 years, considerable research has been devoted to the nutrition of the rumen microflora. Wide interest has developed in factors affecting their cellulolytic activity. Hall *et al.* (1955) have studied B vitamin effects, while Bentley *et al.* (1954), Bryant and Doetsch (1955) and El-Shazly (1952) have investigated the role of certain straight and branched chain fatty acids. MacLeod and Murray (1956) and Johnson *et al.* (1957, 1958), studied cellulolytic activity of certain amino acids and fatty acids.

Animal performance studies using supplemental B vitamins and/or fatty acids by Hungate and Dyer (1956), Klosterman and Bentley (1957) and Lassiter *et al.* (1958a, b) have given variable results.

Recently Kamlet (1958) studied the effect of levulinic acid on cellulose digestibility. Levulinic acid added at the rate of 0, 5, 10, 15, 20 and 25 lb. per ton to a basal ration of oat straw, molasses and grain mix fed at a 6:1:1 ratio, respectively, resulted in a 21.4, 28.2, 34.6, 39.0, 40.2 and 41.2% cellulose digestibility for the respective levels of added levulinic acid.

Levulinic acid can be prepared readily and inexpensively from cane or beet molasses, wood wastes, starches and cellulose. Therefore, the following experiments were undertaken to test further the value of this compound as a cellulolytic agent for ruminants when fed with various roughages.

Experimental Procedure

Part 1. Four bred dairy heifers averaging approximately 750 lb. each were individually fed twice daily four rations in a series of digestion trials employing a 4 x 4 Latin square design. Each trial consisted of a 10-day preliminary period followed by a 5 to 7-day period in which fecal samples were collected using the equipment described by Gorski *et al.* (1957). The roughage used was either average quality, second cutting chopped alfalfa hay or chopped oat straw and it was fed nearly to the level of the animal's appetite. With the alfalfa hay this was approximately 14 lb. per day while with oat straw the level was approximately 12 lb. per day. The roughage was sprayed at each feeding either with molasses or with a molasses-levulinic acid mixture sufficiently high in levulinic acid so that 1% of the total dry matter intake was from levulinic acid. Total molasses fed daily was 3 lb. When oat straw was the roughage used, 3 lb. daily of a basal grain ration was also fed. The basal grain ration contained the following constitutents in the proportions indicated: mill run, 18.20%; ground oats, 19.20%; rolled barley, 25.61%; ground peas, 22.77%; molasses, 8.86%; cottonseed meal 3.40%; steamed bone meal, 0.98%; iodized salt, 0.98%.

The various treatments were as follows: (A) alfalfa hay plus molasses; (B) alfalfa hay + molasses + levulinic acid; [6] (C) oat straw + grain ration + molasses; and (D) oat straw + grain ration + molasses + levulinic acid. Total fecal output from each heifer was collected twice daily, composited, sampled and frozen. Samples from each heifer for a 5 to 7-day period were composited, mixed, and a sample of this material dried in an oven at 80° C. for 48 hours, ground and resampled. Hay, straw, grain and molasses samples were collected twice daily at feeding time, composited for the 5 to 7-day collection period, and a representative sample taken for analysis.

[1] Scientific paper no. 2028, Washington Agricultural Experiment Stations, Pullman, Projects 1242 and 1439.
[2] Department of Dairy Science.
[3] Department of Animal Science.
[4] Research Officer on leave of absence from Research Branch, Canada Dept. Agr.
[5] Present address: Department of Animal Science, University of Manitoba, Winnipeg.

[6] Acknowledgement is made to Crown Zellerbach Corp., Camas, Wash. for supplying the levulinic acid used in this study.

TABLE 1. EXPERIMENTAL RATIONS FED TO WETHERS

Constituent	Diets			
	A	B	C	D
Wheat straw	75.0	75.0	37.5	37.5
Alfalfa hay	....	....	37.5	37.5
Barley	9.0	9.0	15.0	15.0
Molasses	8.0	8.0	8.0	8.0
Cottonseed meal (43%)	5.0	5.0	....	....
Urea	1.0	1.0	....	....
Dicalcium phosphate	1.0	1.0	1.0	1.0
Salt	1.0	1.0	1.0	1.0
Levulinic acid[a]	....	+	....	+

[a] Levulinic acid was added to rations B and D at the rate of 11.35 kilograms per 908 kilograms of ration.

Rumen samples were taken three hours after feeding via stomach tube at the end of each 5 to 7-day collection period and analyzed for volatile fatty acid content by the method of Keeney (1955). Feed and fecal samples were analyzed for cellulose by the method of Crampton and Maynard (1938), and for energy by combustion in the Parr oxygen bomb calorimeter.

Part 2. Four wethers, weighing approximately 210 lb. each, were fed individually one of four experimental rations in a series of digestion trials using a 4 x 4 Latin square design. The rations are shown in table 1. The rations were made isonitrogenous by adding urea and cottonseed meal. Levulinic acid was added to rations B and D at the rate of approximately 25 lb. per ton or 1.25%. The constituents of each ration were mixed and pelleted into 3/16 in. cubes. Animals were fed twice daily, water was available for *ad lib.* consumption, and peat moss was used for bedding. Following an 8-day adjustment period, total feces was collected from each animal for 3 consecutive days according to the method of Schneider *et al.* (1955). The fecal bags were removed twice daily and a measured aliquot of feces taken for analysis. After each collection period the animals were reallotted new rations.

Fecal samples were dried and crude fiber was determined on feed and fecal samples according to the method in A.O.A.C. (1955). Energy was determined on both feces and feeds as in Part 1.

Rumen samples were collected from each animal via a stomach tube 2.5 hours after feeding at the conclusion of each fecal collection period. Microbial activity of rumen ingesta was determined in a Warburg apparatus according to the method of Hungate *et al.* (1955). Manometer readings were begun approximately 90 minutes after the rumen samples were collected.

Analyses of variance were conducted on the data obtained from the Latin square designs. The treatment sums of squares were partitioned into sums of squares due to the various comparisons which were: (1) levulinic vs. no levulinic, (2) alfalfa vs. oat straw plus grain, or alfalfa + wheat straw vs. wheat straw, and (3) interaction between (1) and (2).

Results and Discussion

The results of the digestibility studies are presented in table 2. The addition of levulinic acid to the basal rations fed to either heifers or wethers did not significantly ($P>0.05$) change dry matter, energy, cellulose or crude fiber digestion. In the trial with heifers, a trend toward depression of cellulose digestion was evidenced on both the alfalfa and

TABLE 2. EFFECT OF LEVULINIC ACID ON AVERAGE DIGESTION COEFFICIENTS FOR DRY MATTER, CELLULOSE OR CRUDE FIBER AND ENERGY IN DAIRY HEIFERS AND WETHERS

Kind of animal	Ration	Dry matter	Cellulose	Crude fiber	Energy
Dairy heifers					
	A (Alf.+Mol.)	54.2	50.5	....	53.7
	B (Alf.+Mol.+Lev.)	54.0	46.0	....	54.3
	C (O.St.+Mol.+Gr.)	56.6	56.3	....	57.1
	D (O.St.+Mol.+Gr.+Lev.)	56.8	53.9	....	57.1
	Standard error of the mean	1.2%	2.5%	....	1.4%
Wethers					
	A (Wht.St.)	51.6	....	41.4	45.1
	B (Wht.St.+Lev.)	51.6	....	44.5	45.7
	C (Wht.St.+Alf.)	59.4	....	40.8	54.2
	D (Wht.St.+Alf.+Lev.)	59.1	....	37.9	54.3
	Standard error of the mean	2.1%	....	2.7%	2.4%

TABLE 3. AVERAGE TOTAL VOLATILE FATTY ACID LEVELS AND MOLE PERCENTAGE OF EACH ACID IN RUMEN FLUID IN DAIRY HEIFERS AND WETHERS

Kind of animal	Ration	Acetic	Propionic	Butyric	Valeric or valeric + C_6, C_7, C_8	C_6, C_7, C_8	Total V.F.A. per ml. rumen contents[a]
Dairy heifers							μ moles
	A (Alf.+Mol.)	66.4	18.9	10.6	4.1	...	110.4
	B (Alf.+Mol.+Lev.)	65.4	20.5	9.9	4.2	...	103.7
	C (O.St.+Mol.+Gr.)	65.9	20.3	11.2	2.6	...	90.9
	D (O.St.+Mol.+Gr.+Lev.)	66.8	19.3	10.2	3.7	...	90.5
	Standard error of the mean	....	....	....	...	...	6.2
Wethers							
	A (Wht.St.)	57.6	21.4	13.7	2.8	4.4	95.8
	B (Wht.St.+Lev.)	57.9	21.8	11.3	3.8	4.0	91.6
	C (Wht.St.+Alf.)	58.4	19.5	15.1	2.3	4.5	107.7
	D (Wht.St.+Alf.+Lev.)	57.2	19.9	14.1	4.6	4.1	104.7
	Standard error of the mean	....	....	....	...	...	8.7

[a] During the second collection period rumen samples from all animals were spoiled. The missing values for the 4 x 4 Latin square design were approximated by the method of Yates (1936).

oat straw diets when levulinic acid was added. A similar trend was indicated in the wether digestion trial when the wheat straw-alfalfa diet was supplemented with levulinic acid.

The addition of alfalfa to the wheat straw diet (rations C and D) in the wether digestion trial resulted in an increase in digestibility of energy from 45.4% to 54.3% (19.6% increase) and in digestibility of dry matter from 51.6% to 59.3% (14.9% increase). Increases were significant at one percent and 5% levels of probability, respectively. Energy digestibility and dry matter digestibility of the alfalfa and of the oat straw plus grain diets fed the heifers were comparable. The coefficient for cellulose digestibility increased from 48.2% to 55.1% (14.3% increase) for heifers changed from alfalfa to oat straw + grain. This difference was significant at the 5% level of probability.

Analysis of variance of the data in the trials with both species showed a significant ($P<0.05$) period effect for dry matter, crude fiber or cellulose and energy digestion. Part of this effect may be explained in the wether digestion trial where a palatibility problem was encountered. Initially, each wether was fed 1800 gm. of its respective experimental ration daily, but just after the first collection period, animals receiving rations A (wheat straw) and B (wheat straw + levulinic acid) reduced their intake. This necessitated an adjustment in daily intake finally to 1400 gm.

In the heifer digestion trial, a marked reduction in digestibility of all constituents occurred during the third collection period. This may have been caused by a voluntary reduction in water intake by all animals which occurred as the result of a sudden drop in atmospheric temperature at the beginning of the collection period. The heifers were housed in an open shed throughout the experiment, whereas the wethers were penned in a controlled temperature room.

With both dairy heifers and wethers, rations containing alfalfa appeared to result in higher concentrations of total rumen volatile fatty acids than those containing wheat or oat straw as the only roughage (table 3). However, these differences were not significant at the 5% level of probability. Only small differences existed in molar percent of fatty acids of rumen contents from heifers or wethers fed their respective experimental rations.

On the other hand, differences in microbial activity as measured manometrically on the Warburg apparatus were significant ($P<.01$). During a 55-minute incubation period, gas production measured as mm. Hg. was as follows for the four diets: A (wheat straw), 29.4; B (wheat straw + levulinic acid), 27.2; C (wheat straw + alfalfa), 47.4; D (wheat straw + alfalfa + levulinic acid), 38.8. The activity of rumen samples from animals fed wheat straw + alfalfa were significantly greater ($P<0.01$) than those from animals fed wheat straw as the only roughage. The addition of levulinic acid to the wheat straw or wheat straw + alfalfa diets inhibited microbial activity ($P<0.05$). This suggests that levulinic acid might function as an antimetabolite for rumen microorganisms.

In this experiment digestion was not increased by supplementing roughage rations with levulinic acid. In dairy heifers receiving the basal ration of oat straw plus three pounds grain and three pounds of molasses, cellulose digestibility was 56%. This exceeds by almost 15 percentage points the highest value obtained by Kamlet (1958) when a similar diet was fed and contained 25 lb. of levulinic acid per ton.

Summary and Conclusions

Four bred dairy heifers and four wethers were used in digestibility studies in 4 x 4 Latin square designs. Basal rations of oat straw + molasses + concentrate, or alfalfa + molasses, alone, or supplemented with levulinic acid at approximately 25 pounds per ton were fed to dairy heifers. Basal rations of 75% wheat straw + concentrates, or 37.5% wheat straw + 37.5% alfalfa + concentrates, alone, or with levulinic acid added at about 25 pounds per ton were fed to wethers.

Analysis of variance of the digestibility data indicated that levulinic acid at the level used in these trials, did not significantly ($P>0.05$) alter dry matter, energy, cellulose or crude fiber digestion, and total volatile fatty acids of rumen contents. However, dry matter and energy digestibility by wethers were increased significantly ($P<0.05$) by the addition of alfalfa to the wheat straw diet. Microbial activity of rumen fluid from wethers fed the alfalfa-wheat straw diet was significantly higher ($P<0.01$) than in animals fed wheat straw as the only roughage. Levulinic acid depressed microbial activity ($P<.05$) as measured on a Warburg apparatus.

Literature Cited

A.O.A.C. 1955. Official Methods of Analysis, (8th ed.). Association of Official Agricultural Chemists. Washington 4, D. C.

Bentley, O. G., A. Lahmkuhl, R. R. Johnson, T. V. Hershberger and A. L. Moxon. 1954. The "cellulolytic factor" activity of certain short chained fatty acids. J. Am. Chem. Soc. 76:5000.

Bryant, M. P. and R. N. Doetsch. 1955. Factors necessary for the growth of *Bacteroides succinogenes* in the volatile acid fraction of rumen fluid. J. Dairy Sci. 38:340.

Crampton, E. W. and L. A. Maynard. 1938. The relation of cellulose and lignin content to the nutritive value of animal feeds. J. Nutr. 15:383.

El-Shazly, K. 1952. Degradation of protein in the rumen of the sheep. II. Action of rumen microorganism on amino acids. Biochem. J. 51:647.

Gorski, J., T. H. Blosser, F. R. Murdock, A. S. Hodgson, B. K. Soni and R. E. Erb. 1957. A urine and feces collecting apparatus for heifers and cows. J. Animal Sci. 16:100.

Hall, G., E. W. Cheng and W. Burroughs. 1955. B-Vitamins stimulatory to cellulose digestion by washed suspensions of rumen microorganisms. Acad. Sci. Proc. 62:273.

Hungate, R. E. and I. A. Dyer. 1956. Effect of valeric and isovaleric acids on straw utilization by steers. J. Animal Sci. 15:485.

Hungate, R. E., D. W. Fletcher and I. A. Dyer. 1955. Effects of chlortetracycline feeding on bovine rumen microorganisms. J. Animal Sci. 14:997.

Johnson, R. R., B. H. Dehority and O. G. Bentley. 1958. Studies on the *in vitro* rumen procedure; improved inoculum preparation and the effects of volatile fatty acids on cellulose digestion. J. Animal Sci. 17:841.

Johnson, R. R., B. H. Dehority, O. G. Bentley and A. L. Moxon. 1957. Metabolism of growth factors for rumen microorganisms: Valeric Acid, Valine the Leucines and Proline. Fed. Proc. 16:202.

Kamlet, J. 1958. Preservation and improvement of assimilability of feeding stuffs. U. S. Patent Office, Patent No. 2,831,769.

Keeney, Mark. 1955. Direct chromatographic determination of C_1 to C_6 fatty acids in rumen fluid. Md. Agr. Exp. Sta., Misc. Publ. 238.

Klosterman, E. W. and O. G. Bentley. 1957. Growth factors and hormones in beef cattle feeding. Proc. 12th Distillers Feed Conf., p. 14.

Lassiter, C. A., R. S. Emery and C. W. Duncan. 1958a. The effect of alfalfa ash and valeric acids on the growth of dairy heifers. J. Dairy Sci. 41:552.

Lassiter, C. A., R. S. Emery and C. W. Duncan. 1958b. The effect of valeric acid and a combination of valeric and iso-valeric acids on the performance of milking cows. J. Animal Sci. 17:358.

MacLeod, R. A. and J. F. Murray. 1956. Some factors affecting cellulose digestion by rumen microorganisms *in vitro*. J. Nutr. 60:245.

Schneider, B. H., B. K. Soni and W. E. Ham. 1955. Methods for determining consumption and digestibility of pasture forages by sheep. Wash. Agr. Exp. Sta. Bul. No. 16.
26:301.

Yates, F. 1936. Incomplete latin squares. J. Agr. Sci.

INFLUENCE OF DIETARY CALCIUM AND ZINC ON CALCIUM-45, PHOSPHORUS-32 AND ZINC-65 METABOLISM IN SWINE [1, 2]

R. K. Berry,[3] M. C. Bell, R. B. Grainger and R. G. Buescher

University of Tennessee-Atomic Energy Commission
Agricultural Research Laboratory
Oak Ridge, Tennessee

and

Kentucky Agricultural Experiment Station
Lexington, Kentucky

NUMEROUS investigators have reported parakeratosis to be a zinc deficiency caused by a calcium-zinc interaction. Tucker and Salmon (1955), Stevenson and Earle (1956), Hanson (1956), Luecke *et al.* (1956, 1957), Lewis *et al.* (1957), Bellis and Philip (1957) have demonstrated that when swine were fed a low-zinc ration, additional dietary calcium increased the severity of this disease. It has been postulated that calcium might aggravate parakeratosis by hindering absorption of zinc. Additional calcium has been shown by Lewis *et al.* (1957), and Hoekstra *et al.* (1956) to decrease the zinc content of liver and kidney. However, the data of Newland *et al.* (1958), Whiting and Bezeau (1958), and Beardsley (1958) revealed that an increase in dietary calcium had no effect on zinc absorption. Lloyd and Bell (1958) demonstrated a beneficial effect of high calcium on absorption and retention of zinc in 140-lb. barrows that received a ration containing 140 ppm of zinc.

This study was conducted to ascertain the effects of dietary calcium and zinc upon the absorption of Ca^{45}, P^{32} and Zn^{65} and stable Ca and P.

Experimental

In each of two replicate trials, sixteen barrows averaging 46 lb., were allotted to four lots and fed the following diets: (1) basal; (2) basal + 71 ppm zinc; (3) basal + 0.6% calcium; and (4) basal + 71 ppm zinc + 0.6% calcium. The corn-soybean meal basal (table 1) contained 0.59% calcium, 0.55% phosphorus and 29 ppm zinc. Supplemental calcium and zinc were supplied as $CaCO_3$ and $ZnSO_4$, respectively. The pigs were wormed by self-feeding .06 lb. piperazine per 100 lb. feed for one day. As the water supply contained approximately 2 ppm zinc, all animals were given distilled water *ad libitum*. All galvanized feeders and waterers were painted with liquid plastic to prevent zinc contamination. The pigs were placed in individual concrete lots and fed their respective diets *ad libitum*.

Following a 4-week preliminary period, 4 pigs per dietary treatment were placed in metabolism units to facilitate radioisotope dosing and bleeding. After a 5-day adjustment

TABLE 1. COMPOSITION OF BASAL RATION

Ingredient	Percentage
Corn	74.50
Soybean oil meal	18.00
Dehydrated alfalfa meal	2.81
Fish meal	2.50
$CaHPO_4$	1.04
$CaCO_3$	0.23
$ZnSO_4$	0.00
Salt	0.50
Antibiotic supplement [a]	0.28
Trace mineral mix [b]	0.06
Vitamin premix [c]	0.08

[a] Supplied 10 mg. chlorotetracycline per pound of ration.
[b] Trace mineral mix supplied 0.37 mg. cobalt, 0.11 mg. iodine, 22.26 mg. manganese, 38.40 mg. iron and 9.70 mg. copper per pound of ration.
[c] Vitamin premix supplied 625 I.U. vitamin A, 94 I.U. vitamin D, 5.0 mcg. vitamin B_{12}, 1.2 mg. riboflavin, 5.0 mg. calcium pantothenate, 6.2 mg. niacin, 0.6 mg. pyridoxine, 9.4 mg. choline chloride, 62.5 mg. butylated hydroxy toluene and 227 mg. methionine per pound of ration.

[1] The investigation reported in this paper is published with approval of the directors of the Kentucky Agricultural Experiment Station and the Tennessee Agricultural Experiment Station.
[2] The radioisotopes used in this work were obtained from Oak Ridge National Laboratory on allocation from the United States Atomic Energy Commission. This work was completed under Contract No. AT-40-1-GEN-242 between the University of Tennessee College of Agriculture and the Atomic Energy Commission.
[3] University of Kentucky graduate research participant at University of Tennessee-Atomic Energy Commission Agricultural Research Laboratory.

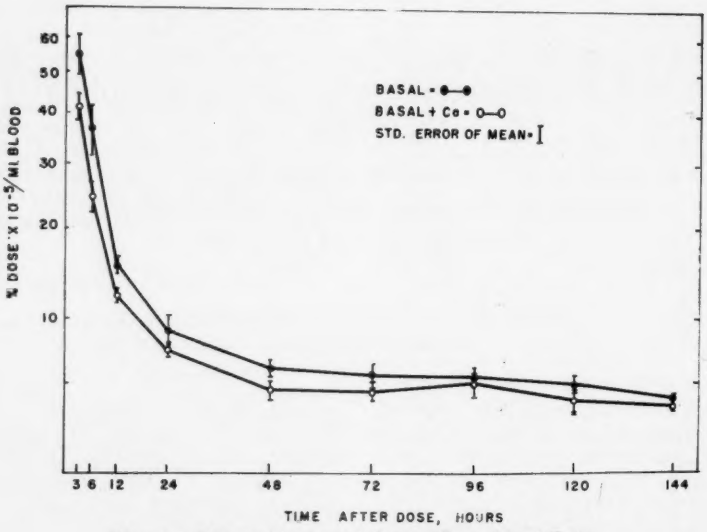


Figure 1. Effect of increased dietary Ca on blood Ca^{45}.

period in the metabolism units, the pigs were orally dosed with 1 mc. Ca^{45} (Trials 1 and 2), 1 mc. P^{32} (Trials 1 and 2) and 0.12 mc. Zn^{65} (Trial 1) and 0.25 mc. Zn^{65} (Trial 2). The Zn^{65} was carrier-free. Blood samples were collected 3, 6, 12 and 24 hours after dosing, and thereafter at 24-hour intervals until the 144-hour collection period was completed. The pigs were sacrificed at the termination of the bleeding study and tissue samples were taken to determine Zn^{65} activity.

Stable zinc was determined by a method

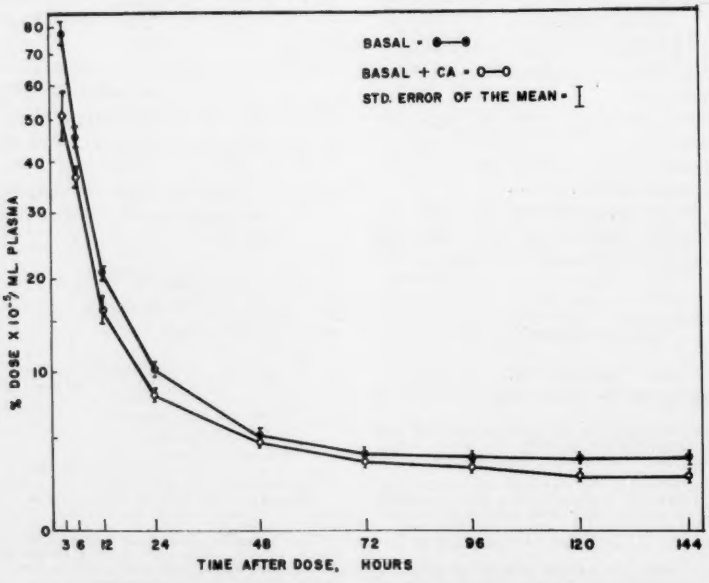


Figure 2. Effect of increased dietary Ca on plasma Ca^{45}.

described by Sandell (1950), using diphenylthiocarbazone as the color complexing agent. Stable calcium was determined by a modification of method of Clark and Collip (1925). The colorimetric method of Fiske and Subarrow (1925) was used for stable phosphorus. Zn^{65} was counted using a well-type gamma scintillation counter. The pulse height was adjusted to exclude Ca^{45} and P^{32}. Calcium and phosphorus radioisotope counting was conducted according to methods previously described by Comar *et al.* (1951).

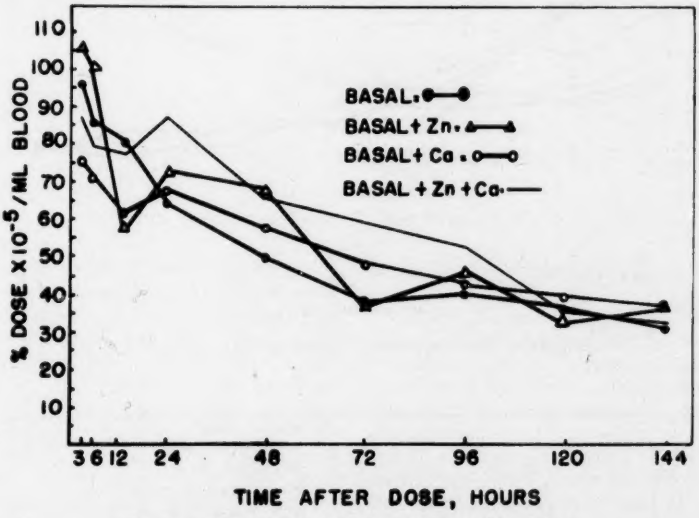


Figure 3. Effect of dietary Ca and Zn on blood P^{32}.

Results and Discussion

Blood and Plasma Ca^{45}, P^{32} and Zn^{65}. Figures 1 and 2 represent a summary of Ca^{45} blood and plasma activity, respectively. As dietary zinc did not affect blood or plasma Ca^{45}, the two normal calcium treatments were summarized and compared with the supplemental calcium treatments to present a clearer picture of the dietary calcium effect. Supplemental calcium depressed ($P<0.01$) the level of Ca^{45} in blood and plasma. This was probably due to the dilution of Ca^{45} in the digestive tract caused by the added dietary calcium. Ca^{45} was absorbed rapidly with a rapid decrease in blood activity from 3 through 48 hours which then remained relatively constant until termination of the metabolism study.

Blood and plasma P^{32} levels are presented in figures 3 and 4, respectively. Added calcium lowered the P^{32} activity in plasma ($P<0.05$). Mayo *et al.* (1960) reported significantly less stable and radioactive plasma phosphorus in swine fed a 0.6% calcium ration compared to pigs fed 0.022% calcium. Additional dietary zinc increased ($P<0.05$) blood P^{32} activity. The distribution of P^{32} between the plasma and cell fractions of blood was calculated from packed cell volume readings and plasma and blood counting data. These data revealed that additional zinc exerted an influence on the P^{32} cell uptake since additional zinc resulted in a significant ($P<0.05$) increase in the cell fraction of P^{32} activity. The plasma activity was highest at 3 hours after dosing; it dropped sharply through the second day and then slowly through the sixth day.

The differences in comparison of fecal and retained stable phosphorus and that of P^{32} were mainly due to the lack of establishment of steady state conditions for the P^{32}; although differences in availability of phosphorus from the diet and from the radioisotope dose may be a minor factor.

Figures 5 and 6 show the Zn^{65} activity in blood and plasma, respectively. Blood Zn^{65} activity remained relatively constant throughout the bleeding period. There was a rapid decrease in plasma activity from the 3-hour level to the 24-hour bleeding period, and then

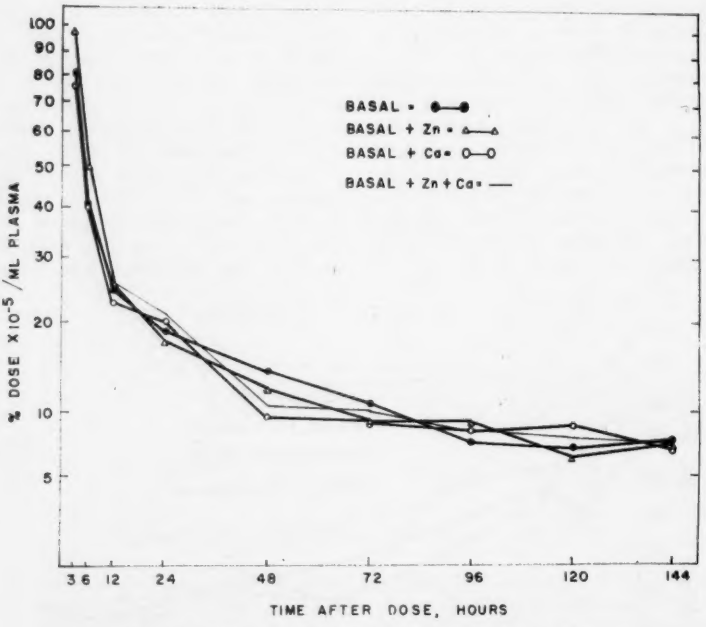


Figure 4. Effect of dietary Ca and Zn on plasma P^{32}.

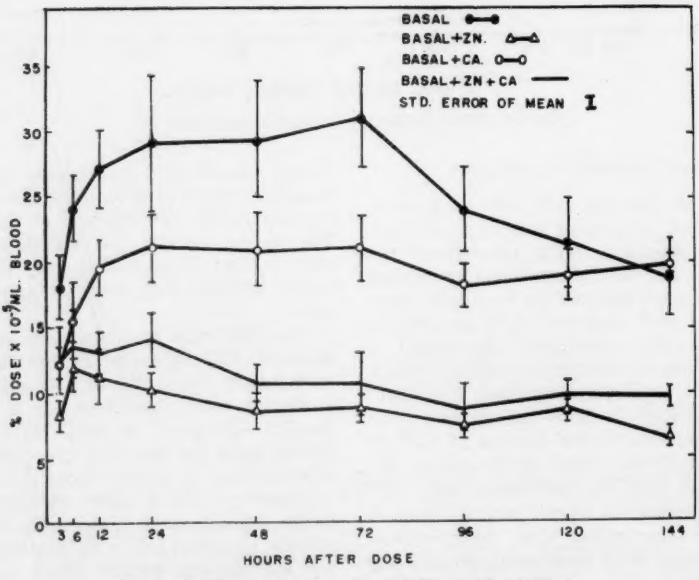


Figure 5. Effect of dietary Ca and Zn on blood Zn^{65}.

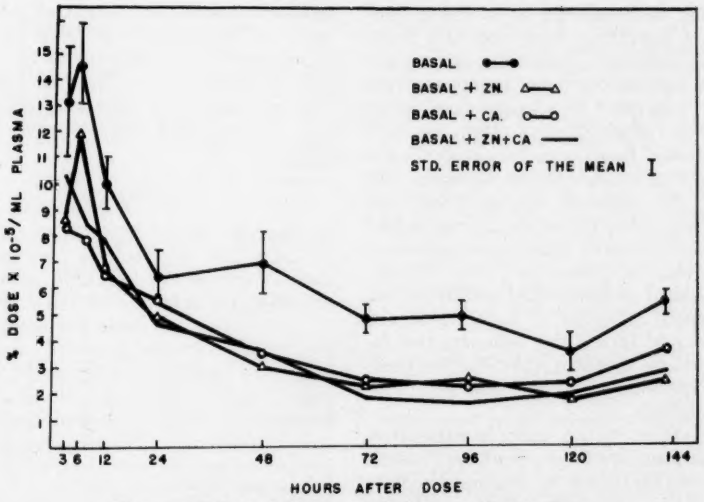


Figure 6. Effect of dietary Ca and Zn on plasma Zn_{65}.

a slow decrease to the 120-hour bleeding. On each treatment, the plasma activity increased between 120 and 144 hours after dosing. Pigs fed the basal ration had the highest Zn^{65} plasma and blood levels throughout the six-day bleeding period. Both dietary additions depressed ($P<0.01$) plasma Zn^{65} activity. There was a highly significant ($P<0.01$) interaction between calcium and zinc on plasma and blood Zn^{65} activity. Supplemental zinc decreased blood Zn^{65} levels ($P<0.01$). Blood Zn^{65} levels were decreased on the low-zinc ration but did not change appreciably in the zinc supplemented ration when 0.6% calcium was added.

Zinc-65 Tissue Retention. Tissue retention of Zn^{65} is summarized in table 2. Statistical analyses of individual tissue data did not show a significant calcium effect on any separate tissue. However, excess calcium supplementation caused an effect on total tissue activity, and it produced a similar effect on each tissue's Zn^{65} retention. Total tissue retention of Zn^{65} was decreased ($P<0.05$) by the addition of 0.6% calcium to a ration containing 29 ppm zinc; however, the sup-

TABLE 2. ZINC-65 TISSUE CONCENTRATIONS[a]

	Dietary treatment							
	Basal		Basal+0.6% Ca		Basal+71 ppm Zn		Basal+Ca+Zn	
Tissue	Total	Per gm.	Total	Per gm.	Total	Per gm.	Total	Per gm.
Liver	199.8	0.233	168.6	0.199	110.9	0.129	160.0	0.201
Lung	30.7	.109	30.4	.102	10.1	.034**	13.7	.048**
Heart	17.9	.108	16.1	.100	6.0	.035**	7.3	.044**
Spleen	8.6	.141	11.1	.132	4.2	.051**	4.1	.058**
Kidney	10.0	.122	9.6	.117	3.9	.045**	4.5	.059**
Pancreas	10.4	.129	8.1	.107	5.3	.057**	5.0	.067**
Femur	7.3	.049	4.9	.029	5.8	.038	5.2	.034
Rib	....	.062	....	.042	....	.050	....	.056
S. I.[b]	....	.086	....	.075	....	.029**	....	.038**
Muscle	....	.044	....	.041	....	.018**	....	.028**
Skin	....	.019	....	.015	....	.007**	....	.008**
Hair	....	.000	....	.000	....	.000	....	.000

[a] All values were multiplied by 100.
[b] S. I.=small intestine.
** $P<0.01$.

plementation with calcium of a ration containing 100 ppm zinc increased ($P<0.05$) total tissue activity. There was a calcium-zinc interaction on Zn^{65} total tissue retention ($P<0.01$). The effect of calcium, when added to a low-zinc (parakeratotic) ration, on Zn^{65} blood levels and tissue retention supports the postulation that excess calcium decreases zinc absorption. The opposite calcium effect that was obtained when excess calcium was added to a zinc supplemented ration is in agreement with the work of Lloyd and Bell (1958). These investigators found that additional calcium increased retention of both stable and radioactive zinc in a 5-day balance trial involving barrows averaging 134 lb. fed practical diets containing 140 ppm zinc and 0.5% or 1.2% calcium.

Zn^{65} retention in the lung, heart, spleen, kidney, pancreas, small intestinal wall, muscle and skin were decreased by additional dietary zinc ($P<0.01$). This zinc effect could possibly be explained by the dilution principle. Feaster *et al.* (1954) used Zn^{65} in steers, Ballou (1959) dosed rats with Zn^{65}, Mayo *et al.* (1960) dosed swine with P^{32} and found that animals dosed with tracers retained a smaller amount of the radio-element as the dietary intake of that mineral was increased.

Chemical and Radiochemical Balance. Both retention and fecal excretion of calcium was increased ($P<0.01$) by the addition of calcium (table 3) which is in agreement with data reviewed by Davis (1959). It is difficult to visualize the retention of an average of 75% more stable calcium by raising the dietary calcium from 0.59% to 1.19% when 0.59% calcium is considered adequate for growing pigs of this age and weight. There was a reduction in feed intake while the pigs were in the collection stalls which may have altered the dietary requirement of calcium when expressed as a percentage of the ration. Addition of calcium also decreased ($P<0.01$) urinary phosphorus excretion, but no measurable effect was found on phosphorus retention or fecal phosphorus excretion, and phosphorus-32 excretion followed the same pattern as stable phosphorus, but Ca^{45} excretion was not measurably related to either calcium or zinc intake. Since Ca^{45} retention was not shown to be influenced by dietary calcium, then the reduction in blood Ca^{45} was probably due to increased deposition of Ca^{45} along with stable calcium in the bone. The addition of calcium or zinc had no measurable effect on urinary or fecal Zn^{65}. Approximately

TABLE 3. AVERAGE CHEMICAL AND RADIOCHEMICAL EXCRETION DATA

	Dietary treatment			
	Basal	Basal+ 0.6% Ca	Basal+71 ppm Zn	Basal+ Zn+Ca
Number of animals	4	4	4	4
	Stable Ca per day (gm.)			
Intake	6.77	14.43	9.15	13.40
Urinary	0.14	0.21	0.20	0.20
Fecal	4.06	8.53**	4.96	7.38**
Retention	2.57	5.69**	3.99	5.82**
	Stable P per day (gm.)			
Intake	6.29	6.63	8.50	6.15
Urinary	1.68	0.71**	1.94	0.56**
Fecal	3.39	4.23	4.11	3.90
Retention	1.22	1.69	2.45	1.69
	Ca^{45} as % of dose			
Urinary	0.3	0.3	0.4	0.2
Fecal	56.0	55.0	45.8	58.2
Retention	43.7	44.7	53.8	41.6
	P^{32} as % of dose			
Urinary	14.4	6.9**	16.4	4.9**
Fecal	27.0	30.6	21.7	29.2
Retention	58.6	62.5	61.9	65.9
	Zn^{65} as % of dose			
Urinary	0.4	0.3	0.4	0.2
Fecal	73.6	69.1	74.3	83.9
Retention	26.0	30.6	25.3	15.9

** $P<0.01$.

75% and 0.3% of the Zn^{65} was excreted in the feces and urine, respectively. Similar results have been reported by Feaster *et al.* (1955) in rats and Feaster *et al.* (1954) in cattle.

It may be that zinc retention in these experiments was influenced by the amount of phosphorus available for deposition. Data in table 3 show that added calcium resulted in a decrease in urinary phosphorus excretion ($P<0.01$), yet retention of phosphorus was not affected. If zinc is deposited along with phosphorus then a more efficient use of absorbed phosphorus would be expected to carry the extra zinc along with it. However urinary phosphorus was not shown to influence urinary zinc as very little of Zn^{65} was excreted in the urine.

Growth Data. Dietary levels of calcium or zinc did not influence rate of gain or feed efficiency of these pigs. Respective daily gains and feed/lb. of gain were: basal 1.57 and 2.96; basal + zinc 1.63 and 2.83; basal + calcium 1.60 and 3.02; and basal + zinc

+ calcium 1.62 and 2.95. No symptoms of parakeratosis were observed in any of these pigs which is in agreement with results of Whiting and Bezeau (1958) showing that pigs weighing more than 35 lb. are less susceptible to parakeratosis than younger pigs.

Summary

Radiotracer techniques were utilized in a 2 x 2 factorial experiment, replicated, involving 32 barrows (average weight 46 lb.), to study the calcium and zinc interrelationship in swine.

Calcium added to a low zinc ration (29 ppm), decreased blood, plasma and total tissue Zn^{65} levels. However, calcium added to a zinc supplemented ration (100 ppm) increased blood and total tissue Zn^{65} activity. Increased dietary calcium lowered blood and plasma Ca^{45} activity, and increased stable calcium retention. Supplemental calcium depressed plasma P^{32} levels and urinary P^{32} excretion.

Increased dietary zinc decreased retention of Zn^{65} in blood, plasma, lung, heart, spleen, kidney, pancreas, small intestinal wall, muscle, and skin. Supplemental zinc exerted no significant effect on Ca^{45} blood or plasma activity but increased blood P^{32} levels. Variation of dietary zinc and calcium did not influence weight gains, and no parakeratosis was observed.

Literature Cited

Ballou, J. E. 1959. Metabolism of Zn^{65} in the rat. UC–48, Biology and Medicine (TID–4500, 14th Ed.).

Beardsley, D. W. 1958. Growth and chemical studies of zinc deficiency in the baby pig. Ph.D. Thesis, University of Illinois, Urbana.

Bellis, D. B. and J. McL. Philip. 1957. Effect of zinc, calcium and phosphorus on the skin and growth of pigs. J. Sci. Food Agr. 8:119.

Clark, E. P. and J. B. Collip. 1925. A study of the Tisdall method for the determination of blood serum calcium. J. Biol. Chem. 63:461.

Comar, C. L., S. L. Hansard, S. L. Hood, M. P. Plumlee and B. F. Barrentine. 1951. Use of calcium-45 in biological studies. Nucleonics 8:19.

Davis, G. K. 1959. Effects of high calcium intakes on absorption of other nutrients. Fed. Proc. 18:1119.

Feaster, J. P., S. L. Hansard, J. T. McCall, F. H. Skipper and G. K. Davis. 1954. Absorption and tissue distribution of radiozinc in steers fed high zinc rations. J. Animal Sci. 13:781.

Feaster, J. P., S. L. Hansard, J. T. McCall and G. K. Davis. 1955. Absorption, deposition and placental transfer of zinc-65 in the rat. Am. J. Physiol. 181:287.

Fiske, C. and Y. Subarrow. 1925. The colorimetric determination of phosphorus. J. Biol. Chem. 66:375.

Hanson, L. E. 1956. Calcium and zinc in swine parakeratosis. Minnesota Swine Feeders Day Bulletin H–143:47.

Hoekstra, W. G., P. K. Lewis, Jr., P. H. Phillips and R. H. Grummer. 1956. The relationship of parakeratosis, supplemental calcium and zinc to the zinc content of certain body components of swine. J. Animal Sci. 15:752.

Lewis, P. K., Jr., W. G. Hoekstra and R. H. Grummer. 1957. Restricted calcium feeding versus zinc supplementation for the control of parakeratosis in swine. J. Animal Sci. 16:578.

Lloyd, M. K. and M. C. Bell. 1958. Zinc metabolism in swine as affected by calcium. UT–AEC Agr. Res. Lab., ORO 177:12.

Luecke, R. W., J. A. Hoefer, W. S. Brammell and D. A. Schmidt. 1957. Calcium and zinc in parakeratosis in swine. J. Animal Sci. 16:3.

Luecke, R. W., J. A. Hoefer, W. S. Brammell and F. Thorpe, Jr. 1956. Mineral interrelationships in parakeratosis of swine. J. Animal Sci. 15:347.

Mayo, R. H., R. K. Berry, R. G. Buescher and M. C. Bell. 1960. The effects of dietary calcium and phosphorus on Sr^{89} and P^{32} metabolism in pigs. 5th Int. Cong. on Nutr. Abstr. p. 5.

Newland, H. W., D. E. Ullrey, J. A. Hoefer and R. W. Luecke. 1958. The relationship of dietary calcium to zinc metabolism in pigs. J. Animal Sci. 17:886.

Sandell, E. B. 1950. Colorimetric Determination of Traces of Metals, 2nd ed. Interscience Publishers, Inc., New York.

Stevenson, J. W. and I. P. Earle. 1956. Studies on parakeratosis in swine. J. Animal Sci. 15:1036.

Tucker, H. F. and W. D. Salmon. 1955. Parakeratosis or zinc deficiency in the pig. Proc. Exp. Biol. Med. 88:613.

Whiting, F. and L. M. Bezeau. 1958. The calcium, phosphorus and zinc balance in pigs as influenced by the weight of pig and the level of calcium, zinc and vitamin D in the ration. Can. J. Animal Sci. 38:109.

IMPROVEMENT OF BARLEY RATIONS FOR SWINE. III. EFFECT OF FIBER FROM BARLEY HULLS AND PURIFIED CELLULOSE IN BARLEY AND CORN RATIONS [1, 2]

L. M. LARSEN AND J. E. OLDFIELD

Oregon State College,[3, 4] *Corvallis*

LIMITATION of available dietary energy has been postulated as an important consideration in inferior performance of swine fed barley rations in contrast to those fed similarly-supplemented low fiber grains. This contention has received support at this station (Oldfield and Anglemier, 1957; Anglemier and Oldfield, 1957) and elsewhere (Heitman, 1956) through increased rate of gain and improved feed utilization observed upon addition of fat to barley rations. The influence of the hull in determining nutritive value of barley has been implied by Wright (1942) who found that the feeding value of barley grain was proportional to its weight per bushel. Further, Joseph (1924) reported superiority of hull-less varieties over regular varieties of barley in supporting growth of swine.

Although quantity of fiber in swine rations has received a great deal of attention, only limited work has been done to date on the effect of fiber quality or composition. Forbes and Hamilton (1952) found variations in growth rate and feed utilization in swine due to qualitative differences in fibers from different sources, and Crampton *et al.* (1954), Dinusson *et al.* (1956) and Hochstetler *et al.* (1959) have noted further that fibrous feeds differed in their growth-depressing effects. Differences have been attributed to lignification of the materials and/or chemical variation in the fiber itself.

Barley hull fiber acts as a diluent of available nutrients in the swine ration, and may also contain factors which physically or chemically inhibit nutrient digestion, absorption or utilization. Growth inhibitors in barley have been suggested in work with poultry (Jensen *et al.*, 1957; Fry *et al.*, 1958; Arscott *et al.*, 1960), however positive proof for their existence is lacking. Jensen *et al.* (1959) suggested that the growth-inhibiting effect of oat hulls on swine is mediated through dilution of digestible nutrients of the ration and by lowered feed intake. Parallel information on barley hulls is not available.

This paper describes two experiments designed to investigate response of growing swine to barley and corn rations in the presence of fiber supplied by either barley hulls or purified wood cellulose, and to evaluate the effect of these two fiber sources on digestibility of a pearled barley ration.

Experimental

Experiment 1. Forty-eight weanling Berkshire pigs were utilized for this study. They were arranged in two equal replicates placed on experiment 3 weeks apart. Two barrows and two gilts from each replication were randomly assigned to each of six experimental treatments.

The basal ration consisted of ground grain 79%, solvent-extracted soybean oil meal 10%, sun-cured alfalfa meal 7.5%, herring meal 2%, oyster shell flour 1% and iodized salt 0.5%. All rations contained 15 mg. chlortetracycline [5] per pound of mixed feed. The experiment followed a factorial design with 2 grains and 3 modifications of fiber source in treatments imposed as follows: (1) Pearled barley, (2) Regular barley, (3) Pearled barley and purified cellulose, (4) Corn, (5) Corn and barley hulls, and (6) Corn and purified cellulose.

Twenty percent of the weight of the barley kernel was removed in the pearling process, and the material so removed is referred to as "barley hulls". The purified cellulose was prepared by grinding dried bleached sul-

[1] Technical Paper No. 1366, Oregon Agricultural Experiment Station.

[2] A preliminary report of a phase of this work was presented before the meeting of the Western Section of the American Society of Animal Production, Logan, Utah, June 1960.

[3] Department of Dairy and Animal Husbandry.

[4] The authors express their appreciation to Albers Milling Company for preparation of the pearled barley and to the Crown Zellerbach Co. for gratis supply of the purified cellulose used in these studies.

[5] Aurofac 10, American Cyanamid Co.

fite wood pulp (Kamyr sheets), a product that is lignin free, through a ⅛ in. screen in a hammermill. The quantity of either barley hulls or cellulose added was calculated to bring the crude fiber level of the rations so treated to that of the regular barley ration. The actual amount of barley hulls added to ration 5 was 20% of the grain component, while 3.3% purified cellulose was used in rations 3 and 6. In all these cases, the substitutions were made at the expense of the grain. All rations were fed as ¼ in. pellets.

Experimental animals were housed individually in 4 ft. x 6 ft. pens, each equipped with self-feeder and automatic waterer. Feed consumption was determined after 6 weeks and at the conclusion of the trial. All animals were weighed weekly and removed from experiment the week they exceeded 200 lb. Backfat measurements were taken at three points on the carcass (Winters, 1955) the day following slaughter. Rations were sampled at intervals and were characterized by proximate analysis (A.O.A.C., 1955) and cellulose determination (Crampton and Maynard, 1938).

Experiment 2. Twelve Berkshire barrows averaging 108 pounds were utilized in a digestion trial in which treatments were: (1) Pearled barley control (experiment 1), (2) Pearled barley diluted by 40% barley hulls, and (3) Pearled barley diluted by 6% cellulose. These rations embody double the quantities of fiber added in experiment 1 to magnify differences existing between fiber sources. The barrows were housed in the individual pens described, without bedding. Total fecal collections were accomplished by constant supervision during daylight hours (approx. 6:00 a.m. to 7:30 p.m.). A five-day collection period followed a four-day pre-trial period, and 20% of each day's fecal output was composited for proximate analysis and for digestible energy determinations.

Statistical examination of data was made by analysis of variance.

Results

Experiment 1. Analyses of ration components and complete rations are summarized in table 1. Animal performance is summarized in table 2, and statistical treatment in table 3.

TABLE 1. CHEMICAL COMPOSITION OF RATIONS AND RATION VARIABLES

Item	Dry matter	Proximate analysis					Cellulose
		Crude protein	Ether extract	Crude fiber	Ash	Nitrogen-free extract	
Feedstuff	%	%	%	%	%	%	%
Regular barley, grain	91.21	11.73	1.52	6.56	2.52	77.67	5.92
Pearled barley, grain	90.67	12.45	1.20	1.85	1.53	82.97	1.45
Corn grain	91.00	10.41	4.21	2.47	1.44	81.47	2.84
Barley hulls	92.64	13.31	4.51	17.98	5.58	58.62	19.48
Purified cellulose	94.18	.....	....	80.36	....	.....	97.30
Ration							
1. Pearled barley, basal	90.24	17.20	2.03	4.12	3.74	72.91	4.67
2. Regular barley	91.54	16.00	1.98	7.25	4.25	70.52	7.93
3. Pearled barley+3.3% cellulose	91.49	16.89	1.82	6.25	3.65	71.39	7.09
4. Corn basal	89.93	15.33	3.99	5.15	3.56	71.97	5.84
5. Corn+20% barley hulls	90.00	15.71	3.98	7.34	4.09	68.88	8.54
6. Corn+3.3% cellulose	90.57	14.98	3.89	6.93	3.68	70.52	8.37

The fraction of the barley kernel removed in the pearling process contained about 18% crude fiber. The resulting pearled barley was lower in fiber content than the corn used (table 1). It is interesting that, whereas over 97% of the purified wood cellulose was recovered in cellulose analysis, only 80% could be accounted for as crude fiber in the conventional A.O.A.C. test. Analyses of entire rations resulted in average recoveries of added cellulose of 74% and 59% by cellulose and crude fiber methods, respectively.

Relative levels of performance of the experimental groups to 6 weeks did not differ from the data for the entire period, therefore only the latter are reported. Also, though

TABLE 2. SUMMARY OF ANIMAL PERFORMANCE AS AFFECTED BY GRAIN AND SOURCE OF FIBER

Treatment	No. of pigs	Av. initial weight	Av. daily gain	Feed/lb. gain	Av. daily feed consumed	Av. backfat thickness
		lb.	lb.	lb.	lb.	in.
Pearled barley	8	42	1.83	3.30	6.0	1.29
Corn	7[a]	49	1.61	3.70	5.9	1.49
Av.	..	..	1.73	3.48	6.0	1.38
Regular barley	8	42	1.69	3.85	6.4	1.19
Corn+barley hulls	7[a]	42	1.49	3.97	5.8	1.28
Av.	..	..	1.60	3.90	6.2	1.23
Pearled barley+cellulose	8	42	1.71	3.58	6.1	1.33
Corn+cellulose	8	44	1.64	3.75	6.1	1.31
Av.	..	..	1.67	3.66	6.1	1.32
Overall barley av.	..	..	1.74	3.58	6.2	1.27
Overall corn av.	..	..	1.58	3.81	5.9	1.36

[a] Two animals were removed from experiment for reasons not attributable to treatment.

significant effects due to replication were observed, the treatment x replication interaction was not significant for any of the factors studied, therefore performance data presented are averages of the two replications.

The average daily gain of pigs fed barley rations was significantly higher ($P<0.01$) than that of those fed corn, and in addition there was a significant difference ($P<0.05$) in their efficiency of feed conversion in favor of the barley-fed pigs. Although this result does not agree with previous experiences at this station (Larsen and Oldfield, 1959, 1960), similar results have been noted by Joseph (1924), Wright (1952) and Dinusson *et al.* (1953) with barleys of exceptionally good quality. The barley used herein was a good quality No. 2 grade, testing 48 lb./bu. In explanation, it may be noted that the corn fed groups consumed on the average 0.3 lb. less feed per day on a dry matter basis, and the crude protein level of the corn rations averaged over 1% less than the barley rations. No attempt was made to equate the different rations with respect to protein. Inconsistent results obtained at various times from similarly-supplemented rations containing the same grain emphasize the nutrient variabilities within grain species and suggest caution in generalizations from "average" data.

The presence of barley hulls in corn and barley rations significantly decreased rate of gain ($P<0.05$) and efficiency of feed conversion ($P<0.01$). Cellulose, when added to pearled barley also tended to depress growth rate and efficiency of feed utilization, but the latter effect was not as pronounced as with barley hulls. On the other hand, cellulose failed to depress gains or feed conversion in animals fed corn rations. This failure of cellulose to lower performance of corn-fed pigs may be explainable on the basis of an increased feed consumption of animals so fed. There was no significant interaction between fiber source and type of grain for average daily gain, feed required per unit gain, or average feed consumption.

TABLE 3. ANALYSIS OF VARIANCE, EXPERIMENT 1

Source	d.f.	Mean square			
		Gains	Feed/lb. gain	Daily feed	Backfat
Lot of pigs	1	0.1943*	0.3185*	0.8680	0.0137
Grain (G)	1	0.2668**	0.3527*	0.4838	0.0699
Fiber source (F)	2	0.0649	0.6979**	0.1820	0.0754
Control vs. hulls	1	0.1267*	1.3230**	0.3630	0.1629*
Control vs. cellulose	1	0.0278	0.1741	0.1114	0.2688
G x F	2	0.0234	0.1256	0.3673	0.0433
Treatment x Lot	5	0.0485	0.0755	0.5071	0.0065
Error	34	0.0260	0.0744	0.2318	0.0270

* $P<0.05$.
** $P<0.01$.

Fiber from barley hulls resulted in a significantly decreased average backfat thickness of pigs on corn and barley rations ($P<0.05$) as compared to the control pearled barley and regular corn rations. Wood cellulose failed to significantly lower backfat thickness. A tendency in this direction was noted on corn rations but not when the major ration component was pearled barley. Backfat thickness was not significantly correlated with either rate of gain or with crude fiber level of the rations. Similar findings have been reported by Crampton *et al.* (1954).

Experiment 2. Digestibility of dry matter, crude fiber and N.F.E. fractions was significantly lower ($P<0.01$) in the ration containing barley hulls than in the pearled barley ration (table 4). In each case the depression was greater with hulls than with purified wood cellulose. Cellulose addition significantly reduced digestibility of dry matter and crude fiber ($P<0.05$), but had no effect on digestibility of N.F.E. Addition of barley hulls and cellulose reduced the digestible energy of the ration to 89% and 95% of the control ration, respectively, but protein digestibility was not significantly affected by either of the two fiber sources.

TABLE 4. APPARENT DIGESTIBILITY OF BARLEY RATIONS AS AFFECTED BY BARLEY HULLS AND PURIFIED CELLULOSE

Treatment	Ration crude fiber level	Digestibility					Digestible energy
		Dry matter	Crude protein	Ether extract	Crude fiber	N.F.E.	
	%	%	%	%	%	%	cal./lb.
Pearled barley	4.51	89	83	−35	51	95	1726
Pearled barley+40% hulls	8.44	77**	81	15	26**	86**	1535
Pearled barley+6% cellulose	9.18	84*	82	15	35*	94	1639

* Significantly different from control ($P<0.05$).
** Significantly different from control ($P<0.01$).

Differences in digestibility of ether extract are not believed of nutritional importance due to the low concentration of this fraction in the diet.

Discussion

These experiments suggest that the barley hull does more than merely dilute available nutrients of the ration with an indigestible material, assuming that purified cellulose acts primarily as a diluent. That barley hulls depressed growth rate and efficiency of feed conversion more than did cellulose is evidence to support this contention, and data on average backfat thickness add further support.

Digestibility data indicate that the observed effects on growth, feed conversion and fat deposition are primarily caused by lowering of the digestibility of energy-supplying nutrients of the diet, a reduction that is greater with fiber from barley hulls than with cellulose. This more pronounced depression with hulls could result from a physical interference with the activity of digestive enzymes due to the form of the fiber, or from direct chemical inhibition of enzyme action. Moreover, efficiency in utilization of digestible energy of a ration appears to be impaired by fiber addition. For example, digestible energy values from experiment 2, adjusted to appropriate fiber level and applied to experiment 1 data for barley groups reveal increases of 553 and 399 Cal./lb. gain respectively for pigs receiving barley hulls and wood cellulose, over the digestible energy of the control ration.

The observation of Forbes and Hamilton (1952) and Crampton *et al.* (1954) that fibers from different sources vary in their effects on growth and fattening is confirmed by this study, but additional information is needed to identify the factors responsible.

Summary

A 2 × 3 factorial experiment was used to compare effects of fiber from barley hulls or purified wood cellulose in barley and corn rations for growing swine. Digestible energy values and digestion coefficients were subsequently obtained with pearled barley rations diluted with either hulls or purified wood cellulose.

Response of pigs to fiber from barley hulls differed from that to fiber from purified wood cellulose. A depressed growth rate and feed

conversion efficiency was noted when barley hulls were included in barley and corn rations as compared to basal pearled barley or corn rations. Cellulose, when added to pearled barley and corn, also tended to depress growth rate, but the increase in feed required per unit of gain was not as great as with fiber from the barley hull. Backfat thickness was reduced more by barley hulls than by cellulose.

Rations containing fiber from barley hulls were less digestible than similar rations containing equivalent amounts of fiber in the form of purified wood cellulose.

It is suggested that the barley hull does more than dilute available nutrients of the ration. The observation that fibers from different sources vary in their effects on growth and fattening is supported by this study.

Literature Cited

Anglemier, A. F. and J. E. Oldfield. 1957. Feeding of various levels of pilchard (California sardine) oil to swine. J. Animal Sci. 16:922.

Arscott, G. H., R. J. Rose and J. A. Harper. 1960. An apparent inhibitor in barley influencing efficiency of utilization by chicks. Poul. Sci. 39:268.

A.O.A.C. 1955. Official Methods of Analysis (8th ed.). Association of Official Agricultural Chemists. Washington, D. C.

Crampton, E. W. and L. A. Maynard. 1938. The relation of cellulose and lignin content to the nutritive value of animal feeds. J. Nutr. 15:383.

Crampton, E. W., G. C. Ashton and L. E. Lloyd. 1954. Improvement of bacon carcass quality by the introduction of fibrous feeds into the hog finishing ration. J. Animal Sci. 13:327.

Dinusson, W. E., M. R. Light, D. W. Bolin and M. L. Buchanan. 1953. Pelleting makes pork. N.D. Agr. Exp. Sta. Bimonthly Bul. 15:162.

Dinusson, W. E., D. W. Bolin and M. L. Buchanan. 1956. Alfalfa and other roughage for growing-fattening swine. N.D. Agr. Exp. Sta. Bimonthly Bul. 19:28.

Forbes, R. M. and T. S. Hamilton. 1952. The utilization of certain cellulosic materials by swine. J. Animal Sci. 11:480.

Fry, R. E., J. B. Allred, L. S. Jensen and J. McGinnis. 1958. Effect of pearling barley and of different supplements to diets containing barley on chick growth and feed efficiency. Poul. Sci. 37:281.

Heitman, H., Jr. 1956. Use of stabilized tallow in swine rations. J. Animal Sci. 15:1046.

Hochstetler, L. N., J. A. Hoefer, A. M. Pearson and R. W. Luecke. 1959. Effect of varying levels of fiber of different sources upon growth and carcass characteristics of swine. J. Animal Sci. 18:1397.

Jensen, L. S., R. E. Fry, J. B. Allred and J. McGinnis. 1957. Improvement in the nutritional value of barley for chicks by enzyme supplementation. Poul. Sci. 36:919.

Jensen, A. H., D. E. Becker and S. W. Terrill. 1959. Growth inhibitory effect of oat hulls in rations for growing-finishing swine. J. Animal Sci. 18:1356.

Joseph, W. E. 1924. Feeding pigs in a dry lot. Mont. Agr. Exp. Sta. Bul. 169:47.

Larsen, L. M. and J. E. Oldfield. 1959. Improvement of barley rations for swine. I. Effects of water treatment and enzyme supplementation. J. Animal Sci. 18:1173 (Abstr.).

Larsen, L. M. and J. E. Oldfield. 1960. Improvement of barley rations for swine. II. Effects of pelleting and supplementation with barley malt. J. Animal Sci. 19:601.

Oldfield, J. E. and A. F. Anglemier. 1957. Feeding of crude and modified menhaden oils in rations for swine. J. Animal Sci. 16:917.

Winters, L. M. 1955. A study of methods of appraising swine carcass quality. Ann. Report of the Hormel Institute. p. 59.

Wright, T. 1942. Barley. Various weights for fattening pigs. S.D. Agr. Exp. Sta. Bul. 366.

HEMOGLOBIN LEVELS OF LAMBS FROM BIRTH TO EIGHT WEEKS OF AGE AND THE EFFECTS OF IRON-DEXTRAN ON SUCKLING LAMBS [1, 2, 3]

R. C. Holz,[4] T. W. Perry, and W. M. Beeson

Purdue University Agricultural Experiment Station

LITTLE information is present in the literature on the expected hemoglobin levels of lambs during the first few weeks of life. Holman (1945), Reida and Hathout (1957), Huisman *et al.* (1958), Loggins *et al.* (1960), and Perry *et al.* (1960) indicate expected values and enumerate some of the factors found to affect hemoglobin levels of sheep, but most of these studies dealt with animals other than newly born or suckling lambs. Thomas and Wheeler (1932) produced anemia experimentally in lambs by placing them in cages and feeding them milk exclusively. Iron and copper supplementation cured the syndrome. Wheeler (1935) reported that hemoglobin levels of lambs in a field trial reached minimum levels at about 3½ weeks of age, but levels increased without treatment by 8 weeks of age to levels near those found at birth.

Since injectable iron-dextran complex was developed by London and Twiggs (McDonald *et al.*, 1955), it has been extensively used to treat anemia in humans and to treat and prevent anemia in pigs (Barber *et al.*, 1955; Brownlie, 1955; McDonald *et al.*, 1955; Dale and MacKay, 1958; Gwatkin and L'Ecuyer, 1959; Rydberg *et al.*, 1959; Ullrey *et al.*, 1959; Wahlstrom and Juhl, 1960; and Zimmerman *et al.*, 1958, 1960). Hardman and co-workers (1959) found no significant increase in weight gains when lambs were injected with 200 mg. of iron as iron-dextran during the first day of life, but hemoglobin levels were consistently higher for the treated group. Swenson (1960) indicated a significant response in both hemoglobin levels and weight gains when lambs were injected with iron-dextran.

The purposes of the present study were: (1) to determine hemoglobin levels of lambs during the first 24 hours of life, (2) to determine the hemoglobin pattern of suckling lambs during the first few weeks of life, (3) to determine if anemia existed in suckling lambs in drylot conditions, (4) to determine if a significant relationship existed between hemoglobin levels and rate of gain, and (5) to assess the effects of iron-dextran injections on suckling lambs.

Materials and Methods

Two experiments were conducted. The first experiment, involving 16 lambs, was a pilot experiment conducted in the spring of 1959. Lambs were placed randomly on one of two treatments at an average age of about one week. Treatments were: (1) no iron injection, and (2) 2 ml. of Armidexan. Lambs were from ewes of similar breeding. Five lambs from Southdown sires and three lambs from Hampshire sires were allotted to treatment 1, and four lambs each from these respective sires were placed in treatment 2. All lambs were docked with an emasculator and males were castrated at about one week of age. All ewes and lambs were confined to the same pen. The ration of the ewes was comprised of alfalfa hay, bonemeal, and salt fed *ad libitum* plus one pound of oats per head daily.

The second experiment was conducted in the spring of 1960 using only female lambs from ewes of Western origin. Ewes in this experiment had been assigned to one of four gestation-lactation rations built around corn silage and alfalfa hay or dehydrated alfalfa meal on the basis of weight, on November 19, 1959. These rations were replaced by one containing predominantly alfalfa silage on April 13. After two weeks on this ration, ewes and lambs were turned out on bluegrass pasture. Ewes had been randomly pasture mated to four Hampshire rams. The first lambs arrived January 25 and the last one arrived March 26.

[1] Contributions from the Department of Animal Science Journal Paper No. 1697, Purdue University, West Lafayette, Indiana.

[2] Data from the thesis submitted by R. C. Holz to the faculty of Purdue University in partial fulfillment of the requirements for the degree of Master of Science.

[3] The authors acknowledge with appreciation the efforts of Dr. M. A. Schooley, Director of Animal Health and Nutrition, Armour and Company, Chicago, Illinois, for supplying the iron-dextran (Armidexan) used in these experiments.

[4] Present address: Cornell University, Ithaca, New York.

Lambs within each gestation lot were allotted to one of three treatments on the basis of: (1) single or twin birth, (2) sex of twin partner if lamb were a twin, and (3) age of dam. Treatments were: (1) no iron injection; (2) three ml. of an iron-dextran compound (50 mg. of iron per ml.) within 24 hours of birth; and (3) three ml. of the iron-dextran compound within 24 hours of birth and an equal dose at 10 days of age for a total of 300 mg. of iron. Lambs were docked at 7 days of age and a blood sample was taken from this incision for hemoglobin determination. Duplicate hemoglobin determinations were made during the first 24 hours of life, at 3 days, 7 days, and weekly thereafter until lambs were 8 weeks of age.

With the exception of the 7-day sample in the second experiment, all blood samples were taken in duplicate from the ear. All samples were drawn directly into Fisher diluting pipettes from the incision. The acid hematin method was used in conjunction with a Fisher Model 6–257 Electrohemometer. The iron-dextran compound used in both experiments contained 50 mg. of elemental iron per ml. In each year, a fortified pelleted creep ration was provided for the lambs.

Results

Experiment 1. Average daily gain over 11 weeks for the control lambs was 0.46 lb. per day compared to 0.55 lb. per day for the group receiving 100 mg. of injectable iron. This 15% difference was not statistically significant. Hemoglobin levels were not significantly different during any one sampling period. A correlation coefficient of r=0.59 (non-significant) was obtained between weight gains and the average of five hemoglobin determinations per lamb. The lowest hemoglobin, 6.2 gm. percent, was recorded for a female lamb at 26 days of age and the highest hemoglobin 15.2 gm. percent, was recorded for a female lamb at two days of age.

Experiment 2. Gains for the 0, 150 and 300 mg. of iron groups were 0.54, 0.56, and 0.58 lb. per day, respectively (table 1). Analysis of variance of averages showed differences in gains by lots to be significant at the 5% level and single lambs gained faster than the twin lambs (1% level).

Hemoglobin levels taken within 24 hours of birth ranged from a high of 19.7 gm. percent to a low of 9.8 gm. percent. The mean birth hemoglobin of 91 lambs was 14.17 gm. percent with a standard deviation of 1.57 (table 2). The average birth hemoglobin of 61 twins was 14.11 gm. percent and 14.32 gm. percent for 30 single lambs. These figures were not significantly different. Female lambs born twin to a male exhibited birth hemoglobin levels of 14.37 gm. percent compared to 13.79 gm. percent for females born twin to another female. These levels were not significantly different. Hemoglobin levels at birth for lambs from aged and yearling ewes were 13.66 and 15.11 gm. percent, respectively, not significantly different. Variation at birth was much greater than at any other age (table 3). Variation appeared to decrease to 8 weeks of age.

Regardless of treatment, hemoglobin levels of all lambs dropped an average of 1.4 gm. percent during the first 3 days of life. The control group reached its lowest level, 8.37 gm. percent, at 3 weeks of age and increased gradually thereafter to 10.73 gm. percent at 8 weeks of age (figure 1). The group receiving the 150 mg. of iron maintained almost a constant 11 gm. percent level from 2 until 8 weeks of age. The second injection at 10 days of age for the group receiving 300 mg. of total iron retarded the hemoglobin decline between 7 and 14 days of age and was followed by an increase to 21 days of age. This then was followed by a decline to a level near 11 gm. percent at 8 weeks of age.

Mortality for the 0, 150 and 300 mg. iron injection treatments was 30.5%, 38.6% and 13.5%, respectively.

Discussion

The result that rate of gain for the non-injected lambs was not significantly different from the rate of gain of injected lambs is in agreement with the work of Hardman *et al.* (1959). However, Swenson (1960) found significant differences in gain between injected and non-injected lambs. Rates of gain in the second experiment, evaluated by averages of averages, showed non-significant increases in rates of gain of 4.2% and 7.6% over the control group for the 150 and 300 mg. iron injections, respectively. The consistency of improvement in rate of gain in these experiments and of those of other workers would seem to indicate a small improvement in gains when iron-dextran is administered.

It is evident that iron-dextran, administered during the first 10 days of life, increased hemoglobin levels to 6 weeks of age.

TABLE 1. AVERAGE DAILY GAINS IN POUNDS OF TWIN AND SINGLE LAMBS RECEIVING DIFFERENT LEVELS OF IRON-DEXTRAN INJECTIONS

	Twins		Singles		Total	
Mg. of iron	No.	A.D.G.	No.	A.D.G.	No.	A.D.G.
0	13	0.52	11	0.57	24	0.54
150	12	0.52	13	0.61	25	0.56
300	10	0.51	13	0.66	23	0.58
Average	35	0.51	37	0.61	72	0.56

It is also evident that the 300 mg. treatment used here gave higher hemoglobin values than did the 150 mg. treatment between 14 and 35 days of age as indicated by a one-tail Newman-Keul test (Snedecor, 1956).

The blood picture would indicate that iron-dextran is not appreciably incorporated into hemoglobin up to the third day of life when it is administered during the first day of life, but maximum use is made of it for hemoglobin synthesis between the third and seventh days of life. Other literature had not previously defined this lack of use up to the third day, but Stewart (1958) states iron-dextran is 85% absorbed by the third day following injection and 63.5% is incorporated into hemoglobin by the seventh day post injection.

Under the conditions of this study, using lambs from ewes of Western origin and Hampshire rams, a value of 11.25 gm. percent would be considered a satisfactory level to maintain, but this may require revision upward if higher levels of iron-dextran result in higher hemoglobin levels, greater gains, and less death loss. With this value taken as normal, mild anemia developed, but gains were not seriously affected by it. There was a high correlation between hemoglobin of experiment 1 and gains, but a high correlation did not exist between these two in the second experiment.

Consistently higher hemoglobin levels were found in twins than in single lambs during the eight week period. This is to be expected when the growth rates, 0.51 lb. per day and 0.61 lb. per day for twins and singles, respectively, are considered to have come largely from milk. If the bodies of lambs contain similar amounts of iron as was found by Venn *et al.* (1947) for pigs, and ewe milk contains 0.266 ppm of iron (Davies, 1939), 185 pints of milk could supply the calculated need of 8.1 mg. per day to sustain the 0.61 lb. per day growth rate. Only 0.37 lb. per day of the creep pellet would be needed to supply the same amount of iron.

Summary

Two experiments were conducted to determine the effects of iron-dextran injections on lambs to ascertain facts concerning hemoglobin levels of young lambs. Rate of gain, hemoglobin levels at birth, 3 days, 7 days, and weekly thereafter, and livability were factors investigated. In 1959, a control group was compared to a group which received 100 mg. of iron as iron-dextran (Armidexan) at one week of age. Hemoglobin levels of control lambs dropped while hemoglobin levels of injected lambs increased following treatment. Weight gains of injected lambs were 15% better than control lambs.

TABLE 2. HEMOGLOBIN LEVELS OF TWIN AND SINGLE LAMBS RECEIVING THREE DIFFERENT LEVELS OF IRON-DEXTRAN

Type of birth	Mg. of iron	Age in days										Average, all ages
		Birth	3	7	14	21	28	35	42	49	56	
Twin	0	13.39	12.52	10.89	9.05	8.76	9.07	9.48	10.05	10.65	10.64	10.45
	150	14.09	12.74	12.56	11.03	10.84	10.79	11.37	11.39	11.20	11.17	11.72
	300	14.98	13.18	13.11	11.98	12.38	12.30	11.91	11.58	11.43	11.21	12.41
	Av.	14.15	12.81	12.19	10.69	10.66	10.72	10.92	11.01	11.09	11.01	11.53
Single	0	13.25	12.03	10.22	7.89	7.98	8.11	8.60	9.20	10.25	10.82	9.84
	150	15.22	13.37	12.38	10.88	10.96	10.75	10.75	10.81	10.89	11.02	11.70
	300	14.36	12.65	12.13	11.10	11.56	11.60	11.48	11.41	10.97	11.06	11.83
	Av.	14.28	12.68	11.58	9.96	10.17	10.15	10.28	10.47	10.70	10.97	11.12

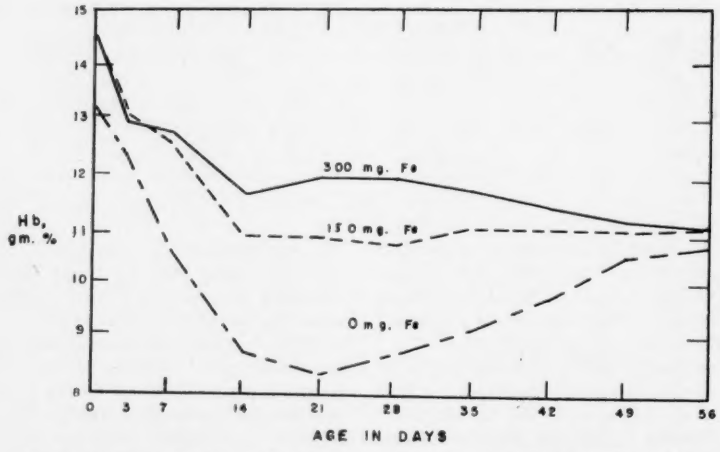


Figure 1. Hemoglobin levels of lambs receiving three different levels of iron-dextran injections.

In 1960, ewe lambs only were allotted to treatments of: (1) no iron injection, (2) 150 mg. of iron (Armidexan) during the first 24 hours of life, and (3) 300 mg. of iron (Armidexan) injected in equal doses during the first 24 hours of life and at 10 days of age. Respective weight gains for these treatments were 0.54, 0.56, and 0.58 lb. per day. Hemoglobin level at birth for all lambs averaged 14.17 gm. percent with a standard deviation of 1.57 gm. percent. No significant differences were noted in birth hemoglobin between twins and single lambs, twin lambs with male vs. female partners, nor between lambs from yearling ewes as opposed to lambs from aged ewes. Average drop in hemoglobin level during the first three days of life was 1.4 gm. percent. Control lambs reached the lowest hemoglobin level, 8.37 gm. percent, at 21 days of age, a figure slightly less than the 14-day level. The group receiving 150 mg. of iron maintained an essentially constant level of 11 gm. percent from 2 to 8 weeks of age. The group receiving 300 mg. of iron maintained higher hemoglobin levels than the group receiving 150 mg. of iron from the second to the sixth week. The effect of iron-dextran on hemoglobin level was significant at P=.0005. Mortality rates for the 0, 150 and 300 mg. iron treatments were 30.5%, 38.6% and 13.5%, respectively.

TABLE 3. ABBREVIATED ANALYSIS OF VARIANCE OF HEMOGLOBIN LEVELS

Source of variation	D.F.	Mean square	F, observed
Total	719	.....	....
Error a	48	6.24	....
Error b	432	1.07	....
Births	1	9.65	4.0
Iron	2	87.02	35.8**
Iron x birth	2	2.26	1.0
Age[a]	9	38.65	92.9**
Age x birth	9	0.49	1.2
Age x iron	18	2.92	7.0**
Age x iron x birth	18	.29	1.0
Error a divided by harmonic mean[b]	...	2.43	....
Error b divided by harmonic mean[b]	...	0.42	....

[a] From this point downward, sources are tested by error b divided by harmonic mean because of disproportionate subclass numbers (Snedecor, 1956, Sec. 12.16).
[b] Harmonic mean of averages used was 2.57.
** Significant at P<.01.

Literature Cited

Barber, R. S., R. Braude and K. G. Mitchell. 1955. Studies on anemia in pigs. I. The provision of iron by intramuscular injection. Vet. Rec. 67:348.

Brownlie, W. M. 1955. The treatment of piglet anemia. Vet. Rec. 67:350.

Dale, D. G. and V. G. MacKay. 1958. Observations on the effect of infected iron-dextran on weight gains and hemoglobin levels of baby pigs on an early weaning schedule. Can. J. Comp. Med. Vet. Sci. 22:371.

Davies, W. L. 1939. The Chemistry of Milk. Chapman and Hall, Ltd., London, England.

Gwatkin, R. and C. L'Ecuyer. 1959. Test of some injectable iron products in pigs. Can. J. Comp. Med. Vet. Sci. 23:29.

Hardman, G. V., J. G. Mattern, Jr., J. L. Perkins, L. Dozsa and J. A. Welsh. 1959. Hemoglobin and hematocrit values in suckling lambs as influenced

by iron-dextran injections. J. Animal Sci. 18:1558 (Abstr.).

Holman, H. H. 1945. Studies on the haemotology of sheep. IV. Erythrocytic and thrombocytic pictures and variations in physical attributes. J. Comp. Path. 55:146.

Huisman, T. H. J., G. VanVliet and T. Sebens. 1958. Sheep hemoglobin. Nature 182:171.

Loggins, P. E., J. T. McCall and J. R. Crockett. 1960. Relationship of hemoglobin levels and body weight of Hampshire, Rambouillet, and Florida Native Ewes at different seasons. J. Animal Sci. 19:653 (Abstr.).

McDonald, F. F., D. Dullop and C. M. Bates. 1955. An effective treatment for anemia of piglets. British Vet. J. 111:403.

Perry, T. W., R. C. Holz, W. H. Smith, W. M. Beeson and M. P. Plumlee. 1960. The effect of size of grind and level in the ration of dehydrated alfalfa meal of trace minerals and implanted tranquilizer on the performance of fattening lambs. J. Animal Sci. 19:1031.

Reida, H. and A. F. Hathout. 1957. The haemotological examination of the blood of normal sheep. British Vet. J. 113:251.

Rydberg, M. E., H. L. Self, T. Kowalczyk and R. H. Grummer. 1959. The effectiveness of three different methods of iron administration to young pigs. J. Animal Sci. 18:410.

Snedecor, G. W. 1956. Statistical Methods. (5th ed.). The Iowa State College Press, Ames, Ia.

Stewart, T. 1958. The pharmacology of iron-dextran. Proc. Symp. Baby Pig Anemia, Feb. 24, 1958. Chicago, Illinois.

Swenson, M. J. Personal communication February 29, 1960. Iowa State University, Ames, Iowa.

Thomas, B. H. and S. S. Wheeler. 1932. The efficacy of copper in the regeneration of hemoglobin in anemic lambs. Am. Soc. Animal Prod. Proc. 1932. p. 204.

Ullrey, D. E., E. R. Miller, D. R. West, D. A. Schmidt, R. W. Seerley, J. A. Hoefer and R. W. Luecke. 1959. Oral and parenteral administration of iron in the prevention and treatment of baby pig anemia. J. Animal Sci. 18:256.

Venn, J. A. J., R. A. McCance and E. M. Widdowson. 1947. Iron metabolism in piglet anemia. J. Comp. Path. and Ther. 57:314.

Wahlstrom, R. C. and E. W. Juhl. 1960. A comparison of different methods of iron administration on rate of gain and hemoglobin level of the baby pig. J. Animal Sci. 19:183.

Wheeler, S. S. 1935. Nutritional anemia in lambs. Nat'l Wool Grower. July 1935:12.

Zimmerman, D. R., V. W. Hays, V. C. Speer and D. V. Catron. 1958. Sources, levels, and methods of administration of iron for baby pigs. J. Animal Sci. 17:1224 (Abstr.).

Zimmerman, D. R., V. C. Speer, V. W. Hays and D. V. Catron. 1960. A comparison of intramuscular and intraperitoneal injection of iron-dextran. J. Animal Sci. 19:484.

ENERGY REQUIREMENTS OF GRAZING STEERS

R. P. Kromann, J. H. Meyer and J. L. Hull [1]

University of California, Davis

LITTLE quantitative data can be found on the maintenance requirements for grazing animals even though a large number of cattle and sheep obtain a major portion of their nutrient needs by grazing. Woodman (1957) estimated a greater starch equivalent need by grazing dairy cows than by those fed in the barn or drylot. This estimate was based on the assumption of greater activity by grazing animals in obtaining their forage. Reid *et al.* (1958) estimated, from their data, that grazing animals required an additional 3.4 lb. of total digestible nutrients compared to cattle confined to the barn. Direct comparisons, however, were not made. It was found by Greenall (1959) that grazing wether lambs had greater energy requirements than suggested by standard values.

Many difficulties are involved in obtaining information on the requirements of grazing animals. Notable among these are the measurement of feed intake on pasture and the energy content of the weight gain. This is a report of an experiment on the quantitative requirements of grazing steers and a comparison between nongrazing and grazing steers.

Experimental

Body composition and forage intake were available from an experiment where five lots of steers grazed irrigated pasture at various stocking rates (1.35, 2.25, 3.06, 3.93 and 4.68 steers per acre), making rates of gain from 0.80 to 1.81 lb. per day. The variation in energy gain and forage intake allowed calculation of a regression equation describing the requirements of grazing steers. One lot of steers was fed soilage from the same pasture and served as the nongrazing control fed in drylot, having a reduced activity because of confinement to a small lot (50 x 50 ft.).

A behavior study was included to determine the activity of the various lots. Four 24-hour observation studies were made during a typical grazing period of one week on days 1, 3, 5 and 7. Observations were made every 15 minutes during the 24-hour day and the number grazing, standing, and lying were recorded and calculated as described by Hull *et al.* (1960).

The detailed experimental procedure in this trial has previously been described by Hull *et al.* (1961). The pastures (50% orchardgrass and 50% Ladino clover) were 0.37 acre (26 x 670 ft.); three, five, seven, nine and eleven steers grazed each pasture giving the stocking rates described above; soilage was harvested from the sixth pasture for the nongrazing control lot. Carcass and body composition were estimated on an initial representative group of steers before the 126-day experiment began and on all steers at the end of the trial.

Digestibility and feed intake were measured by the chromogen-chromium oxide technique of Hardison and Reid (1953). TDN was converted to digestible energy by the conversion factor of 2,000 kcal, per lb. TDN. Specific gravity, described and discussed by Garrett *et al.* (1959) and Meyer *et al.* (1960), was used to estimate body composition.

Results and Discussion

Because an accurate estimate of forage intake was essential to the development of the thesis discussed in this paper, a preliminary trial was conducted to recheck the chromium oxide technique as a measure of intake under these conditions. Eight steers were used to compare the chromium oxide concentration in feces collected in grab samples from the rectum to the concentration in a total collection of feces. Four steers were on pasture and four were fed soilage from the same pasture. Superimposed on the design was administration of 20 gm. of chromium oxide once daily for one-half the steers while the remaining steers received two 10-gram portions daily. Grab samples were collected every 2 hours for 36 hours. A total collection was made of all feces by fecal collection bags and harnesses. As had been found by Bran-

[1] Department of Animal Husbandry.

TABLE 1. STEER RESPONSE TO VARIOUS STOCKING RATES

Item	Pasture					Soilage
	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6
No. per lot	3	5	7	9	11	8
Steers per acre	1.35	2.25	3.06	3.93	4.68	3.24
Av. daily gain, lb.	1.81	1.72	1.42	1.31	0.80	1.49
Av. daily gain, kcal.	3.28	2.18	2.17	1.71	1.14	2.64
Daily intake:						
Dry matter, lb.	16.9	14.5	13.8	12.7	13.2	18.0
Digestible energy, mcal.	22.0	19.0	17.1	16.0	16.3	22.8
Predicted digestible energy intake, mcal.[a]	20.8	15.6	16.2	14.3	12.9	17.7
Measured minus predicted digestible energy intake, mcal.	1.2	3.4	0.9	1.7	3.4	4.1

[a] Predicted from the equations given by Garrett *et al.* (1959).

non *et al.* (1954), Davis *et al.* (1958), Hardison and Reid (1953) and Smith and Reid (1955), a mean concentration of chromium oxide at 6 a.m. and 4 p.m. gave essentially the same concentration as that in the total collection and resulted in essentially 100% recovery. There was no obvious advantage in administering chromium oxide twice daily. Hence chromium oxide administered once daily and grab samples of feces collected from the rectum twice daily were adopted.

A further check on the reliability of the chromogen-chromium oxide technique was a comparison of the measured to the estimated (chromogen-chromium oxide) forage intake of the soilage lots. An average of 17.9 lb. of dry matter was fed daily whereas the estimated intake was 18.0 lb. It was therefore shown that the dry matter intake of the pastured steers was accurately estimated in this experiment.

As the stocking rate increased, food and energy intake, weight gain and energy retention decreased (table 1). Some of these data were discussed in detail by Hull *et al.* (1960, 1961).

It was shown in the behavior study, that over 50% more time was spent eating (grazing) by the steers on pasture than by those on soilage (figure 1). It might be assumed from this that greater activity was required for grazing than for eating soilage. Significantly more time was spent idling, either standing or lying, by steers fed soilage than by those grazing pasture.

As the stocking rate was progressively increased from lot 1 through lot 3, significantly more time was spent grazing and less time standing or lying due, no doubt, to greater competition for forage as grazing intensity increased.

From the behavior study, it might be assumed that the greater activity under the pasture treatments would increase the maintenance requirement. This, however, was not the case. Table 1 gives one method for determining if more energy was used for maintenance by the grazing steers compared to those fed soilage. First, the amount of digestible energy consumed is shown in this experiment. Second, the predicted amount of digestible energy these steers would consume was calculated from the prediction equation given by Garrett *et al.* (1959). This equation was obtained from barn-fed steers that had little or no chance for exercise. It might be expected, therefore, that the smallest difference between the measured and estimated digestible energy intake would be for the soilage group rather than the pasture lots because of the lowered activity of those fed soilage. The greatest difference was found, however, for the soilage lot. Furthermore, lots 3 and 4, which were among those spending a great deal of time grazing, showed a small difference between the estimated and measured digestible energy intake.

The data given in table 1 led to the conclusion that with the measurement methods used in this experiment the maintenance requirement for grazing steers was not greatly different from nongrazing steers. Another approach is shown in figure 2 where the digestible energy intake per unit of $W^{3/4}$ lb. is plotted against energy gain for the steers in this experiment and those of Garrett *et al.* (1959).

The slopes of the lines in figure 2 do not differ significantly; hence they do not provide

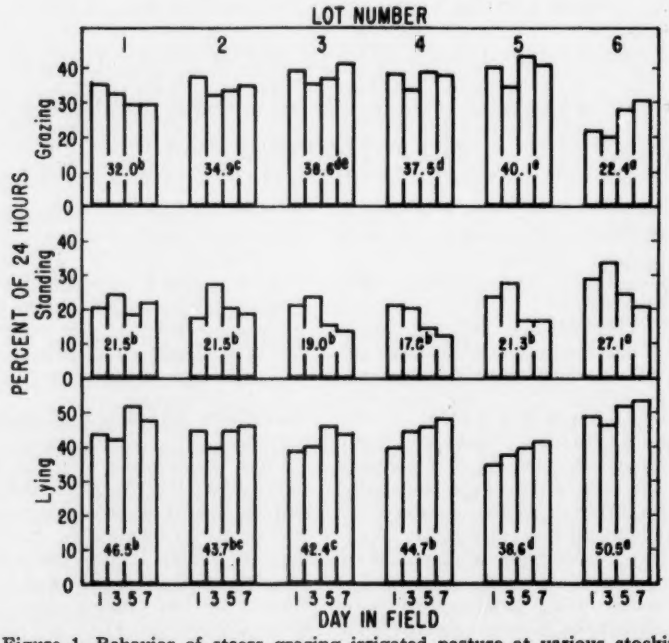


Figure 1. Behavior of steers grazing irrigated pasture at various stocking rates, 1.35, 2.25, 3.06, 3.93 and 4.68 steers per acre for lots 1 through 5, respectively, and time spent eating soilage for lot 6. [a] Values with different superscript letters are significantly different. Values with the same superscript letter, or that letter in combination with another letter, are not significantly different.

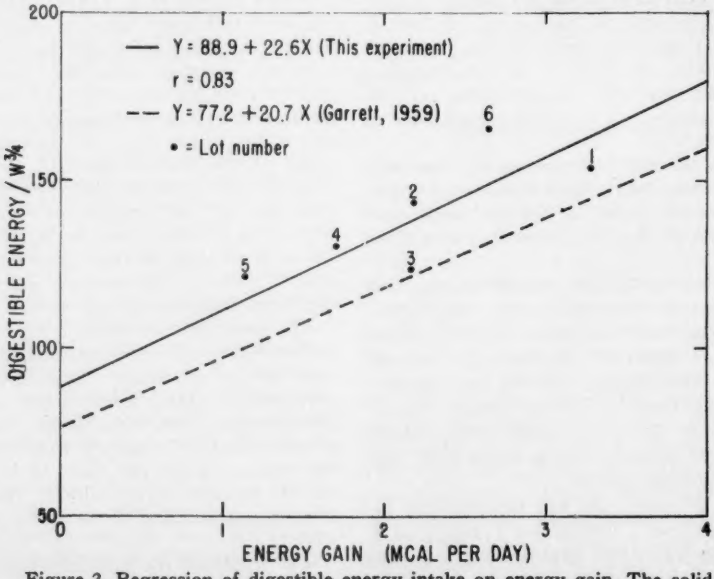


Figure 2. Regression of digestible energy intake on energy gain. The solid line is calculated from the data given in this experiment while the broken line was obtained from data given by Garrett et al. (1959).

evidence of a difference in digestible energy needs per unit of energy gain. The elevations of the lines were not statistically different either and therefore do not give evidence of a difference in the maintenance requirement between these steers and those of Garrett *et al.* (1959).

Summary

An experiment was designed to study the requirements of steers grazing irrigated pasture. Various degrees of grazing intensity produced variations in energy gain and digestible energy intake. Included was a nongrazing control fed the same forage as soilage in a small drylot. A behavior study revealed that from 2.2 to 4.2 more hours were spent by steers grazing forage than eating soilage. No difference, however, was found in the maintenance requirement for digestible energy between steers fed soilage in a small drylot and those grazing the pasture. Furthermore, comparisons between regression equations on digestible energy requirements of these pasture steers and steers fed in drylot showed no significant difference. It is suggested by these data that the extra activity involved in grazing on irrigated pasture does not result in a measurable increase in digestible energy requirements.

Literature Cited

Brannon, W. F., J. T. Reid and J. I. Miller. 1954. The influence of certain factors upon the digestibility and intake of pasture herbage by beef steers. J. Animal Sci. 13:555.

Davis, C. L., J. H. Byers and L. E. Luber. 1958. An evaluation of the chromic oxide method for determining digestibility. J. Dairy Sci. 41:152.

Garrett, W. N., J. H. Meyer and G. P. Lofgreen. 1959. The comparative energy requirements of sheep and cattle for maintenance and gain. J. Animal Sci. 18:528.

Greenall, A. F. 1959. Studies of grazing of crop forages by sheep. III. Intake, maintenance and weight gain requirements of wethers grazing rape. New Zealand J. Agr. Res. 2:639.

Hardison, W. A. and J. T. Reid. 1953. Use of indicators in the measurement of the dry matter intake of grazing animals. J. Nutr. 51:35.

Hull, J. L., G. P. Lofgreen and J. H. Meyer. 1960. Continuous versus intermittent observations in behavior studies with grazing cattle. J. Animal Sci. 19:1204.

Hull, J. L., J. H. Meyer and R. Kromann. 1961. Influences of stocking rate on animal and forage production from irrigated pasture. J. Animal Sci. 20:46.

Meyer, J. H., G. P. Lofgreen and W. N. Garrett. 1960. A proposed method for removing sources of error in beef cattle feeding experiments. J. Animal Sci. 19:1123.

Reid, J. T., A. M. Smith and M. J. Anderson. 1958. Differences in the requirements for maintenance for dairy cattle between pasture- and barn-feeding conditions. Proc. Cornell Nutr. Conf. for Feed Manuf., Nov. 12–16, p. 88.

Smith, A. M. and J. T. Reid. 1955. Use of chromic oxide as an indicator of fecal output for the purpose of determining the intake of pasture herbage by grazing cows. J. Dairy Sci. 38:515.

Woodman, R. E. 1957. Rations for livestock. Ministry Agr. Fisheries and Food, (England) Bul. 48.

INFLUENCE OF SEX AND SIRE ON WEANING WEIGHTS OF SOUTHWESTERN RANGE CALVES [1, 2]

O. F. PAHNISH, E. B. STANLEY, RALPH BOGART [3] AND C. B. ROUBICEK

Arizona Agricultural Experiment Station, Tucson [4]

THE adjustment of weaning weights of range calves to a common sex basis is desirable when the calf production records of cows in a beef cattle breeding herd are compared or when disproportionate sex subclasses hinder the evaluation of sires on the basis of weaning weights of their progeny. Heritability estimates are of value in formulating breeding and selection practices and in predicting progress from selection. It was the purpose of the present study to evaluate the effect of sex on weaning weights of bull and heifer calves produced on desert grassland ranges of the Southwest and to estimate the heritability of weaning weight.

Although the effect of sex on weaning weight under Southwestern range environments has been evaluated (Koger and Knox, 1945; McCleery and Blackwell, 1954; Rice *et al.*, 1954; Rice, 1956), the male calves used in some of these studies were castrated, and the mean weaning ages were all considerably below the 270-day mean age of the calves used in the current study. Estimates of the heritability of weaning weight derived from data collected under Southwestern range environments are lacking.

Experimental Procedure

Weaning weights of 329 bull calves and 332 heifer calves were obtained on two ranches over a period of 6 years (1949–1954). These calves, the purebred progeny of 11 Hereford sires, were produced on desert grassland ranges of the type described by Nichol (1952). The chemical composition of major forage species in this vegetative type was reported by Stanley (1938) and Stanley and Hodgson (1938).

From 1949 through 1951, the breeding herd consisted of essentially a four-sire unit at Sonoita, Arizona (ranch I). The herd was then divided as equally as possible on the basis of ancestry and existing production records into two-sire units. One of these units was then moved to Arivaca, Arizona (ranch II). General management practices were essentially the same on both ranches.

The breeding animals were maintained year-long on desert grassland ranges where they received a commercial supplement containing cottonseed meal, dehydrated alfalfa and trace minerals from weaning time until green forage became available during the spring or summer. Salt was incorporated to limit consumption of the supplement to about 2 lb. per day.

It was considered advisable to separate cows with bull calves from cows with heifer calves prior to weaning, since a few of the bull calves exhibited evidence of sexual activity. The pastures used on each ranch following this separation were, however, similar in forage composition and volume, size and water availability.

The weaning weights, collected on adjacent days on the two ranches, were adjusted to the mean age of 270 days and to a constant age-of-dam equivalent by adjustment factors for bull and heifer calves reported by Pahnish *et al.* (1958a, 1958b). Average, linear regression coefficients of 1.442 and 1.090 lb. per day were used to adjust the weights of bull and heifer calves, respectively, to the standard age. These coefficients differed significantly ($P<.01$). Age-of-dam adjustment factors, also significantly different for the two sexes ($P<.01$), were as follows:

Age of dam	Adjustments (lb.)	
	Bulls	Heifers
(years)	(add)	(add)
3	50	24
4 & 9	25	12
5 – 8	0	0

[1] Arizona Agricultural Experiment Station Technical Paper No. 626. Submitted by the Arizona and Oregon Agricultural Experiment Stations and the United States Department of Agriculture as a contribution to Regional Beef Cattle Improvement Project W-1.

[2] The authors are indebted to the Empire and Arivaca Ranches of Arizona for the cooperative use of livestock and facilities and to W. J. Pistor of the University of Arizona for assistance in the collection of data. Thanks are extended to Lyle D. Calvin (Oregon State University), C. E. Shelby (Regional Swine Breeding Laboratory), and Henry Tucker (The University of Arizona) for statistical advice and assistance.

[3] Department of Dairy and Animal Husbandry, Oregon State University, Corvallis.

[4] Department of Animal Science.

TABLE 1. ADJUSTED WEANING WEIGHTS[a] OF CALVES BY SEXES WITHIN RANCHES AND YEARS

Year	Ranch	Bulls		Heifers		Differences
		No.	Wt.	No.	Wt.	(B–H)
			lb.		lb.	lb.
1949	I	49	519	51	475	44
1950	I	52	539	57	468	71
1951	I	57	491	56	442	49
1952	I	34	570	26	498	72
	II	30	525	26	472	53
1953	I	32	577	33	501	76
	II	25	561	29	507	54
1954	I	26	569	28	470	99
	II	24	529	26	452	77

[a] Adjusted to 270 days of age and to a 5- to 8-year-old dam equivalent.

To evaluate the influence of sex on weaning weights, the data (adjusted as previously described) were treated by variance analyses for multiple classifications with disproportionate subclass numbers (Snedecor, 1946).

The heritability of weaning weight for each sex was estimated by paternal half-sib correlation. The necessary variance components were those attributable to sires within ranches within years and error within sires, ranches and years. Procedures described by Anderson and Bancroft (1952) for unequal subclass numbers were used to determine these components. The standard errors of the heritability estimates were then computed according to the formula proposed by Hazel and Terrill (1945). The standard errors multiplied by 1.96 provided the approximate 95 percent confidence intervals.

Results and Discussion

Sex Effects. Comparisons of the mean weaning weights of the bull and heifer calves, adjusted for differences in weaning age and age of dam, are presented by ranch-within-year subclasses in table 1. Bull calves were heavier than heifer calves in every subclass. Sex differences in weaning weights ranged from 44 to 99 lb. on ranch I over the six-year period and from 72 to 99 lb. over the last three-year period. Sex differences on ranch II over the last three-year period ranged from 53 to 77 lb. In each year in which data from both ranches were available (1952 through 1954), the sex differences were appreciably greater on ranch I. Although ranch II produced the heavier heifer calves in 1953, ranch I produced the heavier calves of both sexes in all other cases.

There was no evidence of a sex x sire interaction within ranches and years (table 2).

TABLE 2. SEX X SIRE INFLUENCE ON WEANING WEIGHTS WITHIN RANCHES AND YEARS (1949 THROUGH 1954)

Source of variation	d.f.	Mean square
Sex x sire within ranch and year	23	1461.8
Calves within sire, ranch and year	597	1962.1

This is consistent with results reported by Koger and Knox (1945), although it is contrary to the findings of Knapp and Phillips (1942).

To evaluate the data summarized in table 1, the weights collected on ranch I were analyzed separately first. This was considered appropriate since data collected on this ranch over the entire six-year period (1949 through 1954) offered the best opportunity for evaluation of the sex x year interaction (table 3).

TABLE 3. ANALYSIS OF SEX AND YEAR EFFECTS ON WEANING WEIGHTS (RANCH I, 1949 THROUGH 1954)

Source of variation	d.f.	Mean square
Sex	1	534819.0**
Year	5	61882.6**
Sex x year	5	7491.0**
Calves within sex and year	489	2194.5

** $P<.01$.

Observations collected on both ranches over the final three years (1952 through 1954) were then treated in a separate analysis to

provide an evaluation of the sex x ranch interaction (table 4).

TABLE 4. ANALYSIS OF SEX, RANCH AND YEAR EFFECTS ON WEANING WEIGHTS (1952 THROUGH 1954)

Source of variation	d.f.	Mean square
Sex	1	437614.0**
Ranch	1	55150.0**
Year	2	26091.0**
Sex x ranch	1	10218.0*
Sex x year	2	5197.5
Ranch x year	2	8355.0*
Calves within sex, ranch and year	327	1939.5

** $P<.01$.
* $P<.05$.

Since the differences in weaning weights attributable to sex effects were highly significant (tables 3 and 4), the advisability of adjusting the weights of all calves to a common sex basis before evaluating cow production records was demonstrated. Such adjustments would be advisable also if weights of bull and heifer progeny are combined to evaluate sire records and the sex-within-sire subclasses are disproportionate.

The highly signficant sex x year interaction (table 3) indicates that the use of a mean difference as a sex adjustment factor year after year, even on the same ranch, may be a questionable procedure. Blackmore *et al.* (1960) drew the same conclusion. It is granted that the analysis of data from ranches I and II (1952–1954) provides converse evidence (table 4), but the opportunity for manifestation of a sex x year interaction was more restricted because fewer years were involved.

The significant sex x ranch interaction ($P<.05$) reported in table 4 suggests the inadvisability of using a constant sex difference in weaning weights as an adjustment factor on different ranches even though the ranches are located within the same general forage type.

In view of the results heretofore presented, it is suggested that the differences between mean weaning weights of bull and heifer calves within ranches within years (computed after the weights are adjusted for differences in weaning age and age of dam) be considered as adjustments for sex effects in commercial practice. This suggested procedure, however, has limitations in small herds. The bull and heifer classes may be too small to provide reasonably reliable estimates of sex effects in some cases or an unequal distribution of sire influences between sex classes may result in error. The investigation of still other methods of adjusting for sex effects, therefore, should be encouraged.

In addition to their use in evaluating sex differences, the analyses presented in tables 3 and 4 lend support to the recommendation of most workers in beef cattle breeding research that weight comparisons for selection purposes be within ranches and within years. The analyses in tables 3 and 4 show that weaning weights differed between ranches ($P<.01$) and among years ($P<.01$). Furthermore, the ranch x year interaction was significant ($P<.05$). These results were obtained even though the ranges of both ranches were located within the same general forage type, the general management procedures were similar on both ranches, the cattle used in the ranch comparisons were initially from a single herd divided on the basis of productions records, and the calves produced on both ranches during the first year of the ranch comparison were by the same sires.

Sire Effects and Heritability Estimates. The results of the variance analyses of the weaning weights of bull and heifer calves are summarized in table 5.

TABLE 5. RESULTS OF VARIANCE ANALYSES OF WEANING WEIGHTS[a] WITH RELATIVE CONTRIBUTIONS OF VARIANCE COMPONENTS AND HERITABILITY ESTIMATES

	Bull calves	Heifer calves
Significance of differences among sires within ranches and years	$P<.05$	$P<.01$
Variance components as percent of total variance:		
Years	11	16
Ranches	15	0
Sires	5	12
Error	69	72
Heritability estimates with 95 percent confidence intervals	0.28 ± 0.32	0.57 ± 0.41

[a] Analyses based on weights adjusted for differences in weaning age and age of dam.

That sires influenced weaning weights was shown. Differences among sires within ranches and years were significant at the 5 percent level in the analysis involving male progeny and at the 1 percent level in the analysis involving female progeny.

The estimated heritability of weaning weight derived from the heifer data by the

paternal half-sib method was higher than that derived by the same method from the bull data (table 5). Both estimates were within the range of estimates cited and reported by Wagnon and Rollins (1959). The difference between the two heritability estimates (0.28 for bulls and 0.57 for heifers) was considered nonsignificant because of the wide overlap of confidence intervals, but the phenomenon illustrated here is consistent with that portrayed by existing within-sex estimates for 6-month weight and other traits (Carter and Kincaid, 1959; Synar, 1958; Diven *et al.*, 1960). The paternal half-sib method of estimation was used in the three cases noted.

Heritabilities of 6-month weight and feeder grade at weaning, as estimated by Carter and Kincaid (1959), were higher for heifers than for steers. Heritabilities of weaning conformation and condition scores, as estimated by Synar (1958), were higher for heifer calves than for bull calves. Synar's data were from the herds involved in the current study. Diven *et al.* (1960), using data from another Southwestern herd, estimated heritabilities of liver and plasma concentrations of vitamin A and carotenoids at weaning time and at about 12 months of age. Their heritability estimates for heifers were, with only two exceptions, higher than those for bulls.

Why the heritability of weaning weight for heifer calves might possibly be higher than that for bull calves is not clear at this time. Other blocks of data should be analyzed to determine whether the observed phenomenon is more than coincidence. In view of the reports by Carter and Kincaid (1959), Synar (1958) and Diven *et al.* (1960), it appears, however, that something other than chance was involved. The possibility that sex-linked genes had an appreciable impact on each of the several traits considered in the four studies seems remote. Perhaps the heifers, in contrast to the males in each study discussed, were at a physiological age more nearly adequate for the expression of genetic differences in weaning weight and other traits. It seems reasonable to presume that the heifers may have been the more advanced physiologically since heifers quite generally are more mature in appearance than males at weaning time. Also, heifers have been found to attain a higher percentage of their mature weight than males by weaning age (Guilbert and Gregory, 1952; Brown *et al.*, 1956).

If it can be established that the heritability of weaning weight and possibly other weaning traits is quite generally higher for heifers than for steers or bulls weaned at the same time, heifer progeny may provide a better measure of the breeding merit of a sire with respect to these traits than steer or bull progeny.

Summary

Sex and sire influences upon the weaning weights of Southwestern range calves were evaluated, and heritability estimates for weaning weight were computed for each sex. Records on 329 bull calves and 332 heifer calves produced by 11 sires on two ranches over a period of 6 years were used. The calves were purebred Herefords weaned at an average age of about 270 days. The weights were adjusted to a standard weaning age of 270 days and to a constant age-of-dam basis preparatory to analysis.

Bull calves were significantly heavier than heifer calves ($P<.01$). The sex differences in weaning weights ranged from 44 to 99 pounds and from 72 to 99 pounds on ranch I for the periods 1949 through 1954 and 1952 through 1954, respectively. Sex differences ranged from 53 to 77 pounds on ranch II for the period 1952 through 1954. The sex x sire interaction within ranches and years was not significant. Because of significant sex x ranch and sex x year interactions, the use of a mean sex difference in weaning weights as a sex adjustment factor on various ranches or even over a period of years on the same ranch was deemed inadequate. The difference between the mean weaning weights within ranches and years, after the weights are adjusted to a standard weaning age and to a common age-of-dam basis, should provide a more realistic adjustment factor for large herds.

Highly significant differences in weaning weights among years and between ranches and a significant ranch x year interaction ($P<.05$) support a recommendation that weight comparisons be confined to single ranches and specific years in commercial selection for improvement of weaning weight.

Sires had a significant influence on the weaning weight of both bull ($P<.05$) and heifer calves ($P<.01$). Within-sex estimates of the heritability of weaning weight by the paternal half-sib method, with approximate 95 percent confidence intervals, were 0.28 ±

0.32 and 0.57 ± 0.41 for bulls and heifers, respectively. The difference between the two estimates as considered nonsignificant, but the higher estimate derived from the heifer progeny demonstrated a phenomenon also reported in other studies when within-sex estimates were calculated for several traits.

Literature Cited

Anderson, R. L. and T. A. Bancroft. 1952. Statistical theory in research. McGraw-Hill, New York. p. 327.

Blackmore, D. W., J. A. Marchello and J. J. Urick. 1960. Differential growth of males and females in different years. Proc. Western Section Am. Soc. An. Prod. 11:VIII–1.

Brown, C. J., M. L. Ray, Warren Gifford and R. S. Honea. 1956. Growth and development of Hereford cattle. Ark. Agr. Exp. Sta. Bul. 570.

Carter, R. C. and C. M. Kincaid. 1959. Estimates of genetic and phenotypic parameters in beef cattle. II. Heritability estimates from parent-offspring and half-sib resemblances. J. Animal Sci. 18:323.

Diven, R. H., O. F. Pahnish, C. B. Roubicek, E. S. Erwin and H. M. Page. 1960. Heritability of vitamin A and carotenoid concentrations in bovine liver and plasma. J. Animal Sci. 19:1218 (Abstr.).

Guilbert, H. R. and P. W. Gregory. 1952. Some features of growth and development of Hereford cattle. J. Animal Sci. 11:3.

Hazel, L. N. and C. E. Terrill. 1945. Heritability of weaning weight and staple length in range Rambouillet lambs. J. Animal Sci. 4:347.

Knapp, Bradford, Jr. and R. W. Phillips. 1942. Differences in performance between sexes in offspring of beef bulls. J. Animal Sci. 1:346 (Abstr.).

Koger, Marvin and J. H. Knox. 1945. The effect of sex on the weaning weight of range calves. J. Animal Sci. 4:15.

McCleery, N. B. and R. L. Blackwell. 1954. A study of the effect of mild inbreeding on weaning weight and grade of range calves. Proc. Western Section Am. Soc. An. Prod. 5:223.

Nichol, A. A. (Revised by W. S. Phillips.) 1952. The natural vegetation of Arizona. Ariz. Agr. Exp. Sta. Tech. Bul. 127.

Pahnish, O. F., Ralph Bogart, E. B. Stanley, C. B. Roubicek and C. E. Shelby. 1958a. Adjustment of weaning weights of range calves to a standard age of 270 days. Proc. Western Section Am. Soc. An. Prod. 9:XLVII–1.

Pahnish, O. F., C. B. Roubicek, E. B. Stanley, Ralph Bogart and C. E. Shelby. 1958b. The influence of age of dam on the 270-day weaning weights of bull and heifer calves. Proc. Western Section Am. Soc. An. Prod. 9:XLVIII–1.

Rice, F. J. 1956. Factors influencing performance in range Hereford cattle. Ph.D. Thesis. University of Missouri.

Rice, F. J., A. M. Kelley and J. F. Lasley. 1954. Length of gestation in Hereford cows and its relation to performance. J. Animal Sci. 13:961 (Abstr.).

Snedecor, G. W. 1946. Statistical Methods (4th ed.). The Iowa State College Press, Ames, Iowa. p. 291, 292.

Stanley, E. B. 1938. Nutritional studies with cattle on a grassland-type range in Arizona. Ariz. Agr. Exp. Sta. Tech. Bul. 79.

Stanley, E. B. and C. W. Hodgson. 1938. Seasonal changes in the chemical composition of some Arizona range grasses. Ariz. Agr. Exp. Sta. Tech. Bul. 73.

Synar, H. H. 1958. The relationships of weaning production factors in range beef cattle. M.S. Thesis. The University of Arizona.

Wagnon, K. A. and W. C. Rollins. 1959. Heritability estimates of post-weaning growth to long yearling age of range beef heifers raised on grass. J. Animal Sci. 18:918.

USE OF HEMATOLOGICAL TECHNIQUES IN STUDY OF "SNORTER" DWARFISM [1, 2]

R. S. TEMPLE [3] AND L. N. HAZEL

Iowa State University, Ames

ACCURATE methods are needed in beef cattle to discriminate between normal appearing animals which are heterozygous for the "snorter" dwarf gene and those homozygous for the normal allele. Although the progeny test is an accurate method of discriminating between "carrier" and "clean" animals (Hazel, 1955), a complete progeny test is unduly expensive and time-consuming, and can be used only for mature bulls. The phenotypic abnormalities of the dwarf animal presumably are associated with physiological peculiarities which might be detectable to some degree in the heterozygous animal. More expedient procedures than the progeny test have been proposed, such as the "profilometer" (Gregory *et al.*, 1951), the radiographic examination of lumbar vertebrae (Emmerson and Hazel, 1956), and the insulin tolerance test (Massey *et al.*, 1956, 1958). Erythrocyte fragility has been studied as a means of discriminating carrier and clean animals by Johnson (1958) and by Lucas and Turman (1959). Average differences between clean and carrier animals can be established by most of these techniques, providing evidence that physical and physiological differences do exist. However, variation within groups has been so large that the techniques have had little value for practical diagnosis.

The blood maintains many of the functions of the body and hence might reflect physiological abnormalities. A more complete hematological study of animals carrying the dwarf gene might show departures from normal. The purpose of this work was to study some hematological differences between clean and carrier Herefords varying in age from young calves to mature cows.

Materials and Methods

One hundred and eighteen plenotypically normal Herefords, either homozygous normal or heterozygous with respect to the dwarf locus, were used in this study. The group included calves, yearlings and cows. Most of these were born in the experimental herd and all were maintained at the experimental farm located at Ankeny, Iowa.

The blood characteristics analyzed were red cell count, white cell count, white cell differential count, percent hemoglobin, percent packed red cells and fragility of erythrocytes. With the exception of the method for determining erythrocyte fragility, conventional hematological laboratory procedures were used. The fragility technique consisted of introducing 0.4 cc. oxalated blood into a colorimeter tube containing 8 cc. of sodium chloride solution. The saline solution and blood were mixed by inverting the tube five times. The tubes were placed in a rack for 30 minutes to permit complete hemolysis and then centrifuged for ten minutes at 1700 R.P.M. The supernatant fluid was decanted and read in a Klett colorimeter against a distilled water blank. The samples having the higher degrees of hemolysis gave the higher colorimeter reading. The colorimeter reading was the recorded observation for erythrocyte fragility.

The strength of the saline solution was 0.58% for most of the experiment. However, the erythrocytes of calves were more fragile than erythrocytes of older animals. In order that readings could be made in a desirable range on the colorimeter, 0.60% saline solution was used when calves alone were studied.

The effect of temperature of the blood at the time the technique was performed was studied. Agreement between replicated samples was highest when the blood and the sodium chloride solution were kept at a constant temperature of 37° C. A repeatability estimate of 0.99 was found for the fragility

[1] Journal Paper No. J.4024 of the Iowa Agricultural and Home Economics Experiment Station in cooperation with North Central Regional Project NC–1, The Improvement of Beef Cattle Through Breeding Methods. Project No. 1055.

[2] Financial support for these studies is acknowledged from the American Hereford Association and the American Angus Association.

[3] Present address, Animal Husbandry Department, Louisiana State University, Baton Rouge, Louisiana.

TABLE 1. MEANS FOR THE VARIOUS BLOOD CHARACTERISTICS BY AGES AND GENOTYPES

	Calves		Yearlings		Cows	
	Carrier	Clean	Carrier	Clean	Carrier	Clean
No. of animals	16	4	6	6	21	13
Erythrocyte fragility	579	668	206	313	130	165
Erythrocyte count in millions	10.80	10.38	7.11	8.54	6.79	7.51
Hematocrit	41.8	38.4	36.4	39.6	39.2	40.1
Percent hemoglobin	9.1	7.1	8.2	9.0	8.3	8.2
White cell count in thousands	12.11	11.16	10.92	10.36	7.82	8.99
Lymphocytes in thousands	7.90	8.48	7.71	6.45	3.36	4.29
Neutrophils in thousands	3.83	1.98	2.57	2.99	2.93	3.28

technique when replicate tests of fragility were made on the same blood sample.

Four experiments were conducted to compare the blood characteristics of carrier and clean animals. The effects of age and atmospheric temperature on the two genotypes were studied first. Sixty-eight animals were used in the first experiment including calves, yearlings and cows. Only one blood sample was taken from each animal when no experimental treatment was being studied. The atmospheric temperature at the time of each bleeding was recorded to study the effects of temperature on the various blood characteristics.

Since several of the blood characteristics showed wide differences between the three age groups, the effect of age was studied more closely on calves of both genotypes. The 58 calves used in this part of the study averaged 248 days of age with a standard deviation of 27.9 days. The calves were bled twice, at intervals of six weeks, in order to study the repeatability of blood values on the same animal. The calves received no treatment such as insulin or adrenalin.

The effect of adrenalin as an aid in discriminating between carrier and clean animals was studied on 24 cows and 24 calves, 12 in each genotype and age sub-group. Preliminary work suggested that the maximum response to adrenalin in most characteristics occurred about 20 minutes after the injection. Also at 20 minutes the maximum difference existed between carrier and clean animals. Blood samples were taken at the time of injection and then 20 minutes and 2 hours after the injection. The dosage of adrenalin used was 0.4 cc. of 1:1000 dilution adrenalin chloride per 100 lb. body weight. The prescribed amount of adrenalin solution was diluted with 8 cc. of 0.85% physiological saline solution before injection.

The recovery rate and production of erythrocytes in the different genotypes were studied by inducing hemorrhagic anemia in four carrier and four clean cows. A 6 in. bleeding cannula was inserted in the jugular vein and 4 cc. of blood per pound of body weight were removed. This operation required from 10 to 30 minutes for each animal. Blood samples were taken by the standard method 1, 2, 3, 4, 5, 9, 13 and 20 days after the original bleeding.

The principal purpose of the study was to develop a technique for discriminating between carrier and clean animals. Statistical analyses were made for all data except that for the work on hemorrhagic anemia, where the numbers were so few. Unequal sub-class numbers existed in the studies involving effect of age but the adrenalin experiment had balanced sub-class numbers. The method of fitting constants was used in analyzing the experiments where unequal subclass numbers existed.

Results

The means of the different ages and genotypes for each blood characteristic studied in the first experiment are shown in table 1. A significant interaction between age and

TABLE 2. THE CORRELATION AND REGRESSION COEFFICIENTS INVOLVING BLOOD CHARACTERISTICS AND ATMOSPHERIC TEMPERATURE AT TIME OF BLEEDING

Characteristic	Correlation	Regression
Erythrocyte fragility	0.01	0.08
Erythrocyte count	0.00	0.00
Hematocrit	−.34**	−.10
Percent hemoglobin	−.28*	−.02
White cell count	−.03	−.09
Lymphocyte count	−.05	−.11
Neutrophil count	−.13	−.24

* $P < .05$.
** $P < .01$.

TABLE 3. THE CORRELATION AND REGRESSION COEFFICIENTS INVOLVING BLOOD CHARACTERISTICS AND AGE OF CALF IN DAYS

Statistic	d.f.	Fragility	Percent hemoglobin	Hematocrit	White cell count
Regression	53	−1.48	0.01	0.03	−.67**
Correlation	53	−.20	0.26	0.21	−.37**

** $P<.01$.

genotype was found in the case of percent hemoglobin, red cell count and neutrophil count. When analyzed within the different ages, significant differences between genotypes were found for percent hemoglobin and neutrophil count but not for red cell count. Genotypes were not significantly different in erythrocyte fragility, white cell count, or lymphocytes, but these three characteristics did show significant differences between ages. These characteristics showed little promise in discriminating between genotypes of individual animals due to the large overlap of genotypes.

The percent hemoglobin and hematocrit were noticeably influenced by atmospheric temperature at the time of the bleeding as shown in table 2. Both of these decreased as temperature increased. Correcting the hematocrit and percent hemoglobin for effects of temperature had little effect in increasing the relationship between these traits and genotype.

In studying the effect of age on the blood characteristics of calves, the only significant regression was that of white cell count on days of age, as shown in table 3.

A second sample was collected from 51 of the 58 calves 6 weeks after the first sample to investigate the changes which occur with age. Product-moment correlations between the same characteristics of the two samples were computed with 47 degrees of freedom after removing effects of sex and genotype. Repeatability for fragility was .53, for hemoglobin was .44, for hematocrit was .23 and for white cell count was .45. Although these values were only moderately high, they were statistically significant for fragility, hemoglobin content and white cell count.

A significant difference between genotypes was found for erythrocyte fragility in the second samples but not in the first. Satisfactory discrimination between genotypes of individual calves from any of the blood characteristics, including erythrocyte fragility, was impossible.

The responses to adrenalin of cows and calves of both genotypes are shown in table 4 for certain characteristics of the blood. The average responses in table 4 appear to be different for carrier and clean cows in both erythrocyte fragility and white cell count, although considerable overlap of the genotype makes accurate classification impossible. The analyses of variance for this experiment are shown in table 5. The average difference between cows and calves was highly significant for all traits. The genotypes differed significantly in erythrocyte fragility and hematocrit (summed over ages and times) but accurate discrimination between genotypes was impossible here also.

The response of four carrier and four clean cows to hemorrhage was studied by the changes that occurred in fragility of eryth-

TABLE 4. AVERAGE VALUES FOR BLOOD CHARACTERISTICS FOLLOWING AN INJECTION OF ADRENALIN

Characteristic	Genotype	Cows			Calves		
		Initial	20 min.	120 min.	Initial	20 min.	120 min.
Fragility	Carrier	150	160	127	222	240	199
	Clean	255	327	222	432	426	359
Percent hemoglobin	Carrier	8.4	8.4	8.4	6.8	6.5	6.8
	Clean	8.7	8.6	8.7	6.9	6.6	6.9
Hematocrit	Carrier	39.5	38.7	41.3	35.9	34.7	35.2
	Clean	41.9	41.6	42.9	37.8	35.3	36.6
White cell count in thousands	Carrier	9.50	8.60	10.05	9.90	12.30	11.70
	Clean	8.80	10.20	10.60	10.60	10.85	12.80

TABLE 5. MEAN SQUARES FOR FOUR CHARACTERISTICS OF THE BLOOD STUDIED AFTER INJECTION OF ADRENALIN

Source of variation	d.f.	Mean squares			
		Fragility	Percent hemoglobin	Hematocrit	Total white cells
Age	1	405662**	114.66**	930.25**	43229**
Genotype	1	854546**	1.26	115.56*	6227
Time	2	46607	.45	28.91	13972*
Age x Genotype	1	35941	.09	8.02	451
Age x Time	2	3718	.24	16.72	1246
Genotype x Time	2	7499	.03	1.63	1969
Age x Time x Genotype	2	5618	.09	4.12	1545
Residual	132	21221	.76	13.51	3039

* $P<.05$.
** $P<.01$.

rocytes, percent hemoglobin, percent packed red cells, erythrocyte numbers and total leukocyte numbers. Erythrocyte fragility increased sharply in both genotypes immediately following induced anemia. The higher fragility was maintained for about 5 days and was followed by a gradual reduction until normal levels were regained about 2 weeks after hemorrhage. The response to hemorrhage was strikingly similar in percent hemoglobin, hematocrit, number of white cells and number of red cells. These characteristics decreased until the fourth day, and then showed a gradual increase back toward the original levels. In most instances the animals returned completely to the original levels in 21 days. The overlap of genotypes was so great in all blood characteristics as to conceal any differences in response which may have existed for different genotypes.

Discussion

The significant differences for erythrocyte fragility observed between genotypes of calves indicate that real differences between averages of these groups do exist. But intra-group variation is large also, and this prevents accurate classification of the genotypes of individual animals. The limited information on yearling steers in this study and results from a preliminary experiment indicate that similar differences between genotypes may exist for yearlings. The results of these data make it appear that significant differences between genotypes can be found for any age if a sufficient number of animals is used or, as in the case of adrenalin administration, if the number of observations on an animal is increased.

Red cell count, percent hemoglobin and hematocrit gave no promise for accurate discrimination of genotypes. Genotypes do not differ, or at least differ very little, in these characteristics so that differences in feeding regime, weather conditions and other managerial factors entirely obscure the small differences in genotypes.

None of these data indicate that carrier and clean animals can be differentiated by total white cell count. In fact, no significant differences between means of the two genotypes were found in any of these experiments. Swiger (1957) found that most accurate prediction could be made from the change in neutrophils between 1 and 2 hours following an injection of adrenalin. He obtained a correlation between actual and predicted genotypes of .71. However, in the present work it was not possible to draw a line of discrimination for the response from 20 minutes to 120 minutes in neutrophil count.

Summary

Red cell counts, percent hemoglobin, hematocrit, red cell fragility, white cell counts and differential white cell counts were studied in 118 Hereford cattle of the homozygous normal and heterozygous genotypes with reference to the "snorter" dwarf gene. The effects of age, sex, atmospheric temperature, adrenalin and hemorrhage on these blood characteristics were studied in the two genotypes. Individual variation was so great for each of these characteristics of the blood that none of them offered a satisfactory means of discriminating between genotypes of individual animals, although significant differences between the means of genotypes were found in several instances.

Literature Cited

Emmerson, M. A. and L. N. Hazel. 1956. Radiographic demonstration of dwarf gene carrier beef animals. J. Amer. Vet. Med. Assoc. 128:381.

Gregory, P. W., W. C. Rollins, P. S. Pattengale and F. D. Carroll. 1951. A phenotypic expression of homozygous dwarfism in beef cattle. J. Animal Sci. 10:922.

Hazel, L. N. 1955. Dwarf research progress. Amer. Hereford J. 46:204.

Johnson, A. G. 1958. The effects of stress upon erythrocyte resistance in pedigree clean, known carrier and dwarf beef cattle. M.S. Thesis. University of Missouri, Columbia, Missouri.

Lucas, L. E. and E. J. Turman. 1959. Comparison of some hematological values for beef cattle of different dwarfism genotypes. J. Animal Sci. 18:1461 (Abstr.).

Massey, J. W., C. W. Foley, M. Melecevic, A. G. Johnson, D. T. Mayer and J. F. Lasley. 1956. Variations in the physiological response to stress in dwarf and normal beef animals. Mo. Agr. Exp. Sta. (Mimeo Dept.)

Massey, J. W., C. W. Foley, A. G. Johnson and J. F. Lasley. 1958. New findings in dwarfism research. Mo. Agr. Exp. Sta. Bul. 704:4.

Swiger, L. A. 1957. Leucocyte response to adrenalin in dwarf and normal beef cattle. M.S. Thesis. Iowa State University, Ames, Iowa.

RESPONSE OF THE YOUNG PIG TO LEVELS OF DIETARY POTASSIUM

A. H. JENSEN, S. W. TERRILL [1] AND D. E. BECKER [2]

Illinois Agricultural Experiment Station, Urbana

HUGHES and Ittner (1942) suggested that 50-lb. pigs required a minimum of 0.15% potassium in the diet. In contrast, Meyer *et al.* (1950) reported that pigs of approximately 35 lb. weight required 0.23 to 0.28% dietary potassium. The latter workers suggested that their higher values reflected the higher level of performance obtained.

Because of the paucity of information on the need for potassium, and since in certain studies at this station a semi-purified diet formulated to be adequate for the 2-week-old pig was found to be deficient in this element, the two experiments reported herein were conducted.

Experimental

Eighty crossbred pigs weaned at 14 to 18 days of age were used in two experiments. In experiment 1 outcome groups of six pigs each were paired by weight, with one of each pair randomly assigned to replicates. Pigs within each outcome group were then randomly assigned to potassium level. Each treatment group of four pigs was confined to a 4 ft. x 8 ft. mesh-floor pen. In experiment 2 outcome groups of eight pigs each were paired by weight, with pigs within each outcome group randomly assigned to potassium level. Each treatment group of two pigs was confined to a small metabolism cage. Feed and water were available at all times. Individual pig gains and lot feed consumption were determined every seventh day. Experiment 1 was 35 days in length; experiment 2 was 28 days in length.

The control ration is shown in table 1. Supplemental potassium was added as potassium carbonate (K_2CO_3).

Upon termination of the second experiment, electrocardiograms were recorded from two litter-mate pairs, one pig of each pair having received the control and one the 0.25% potassium ration. The method of recording was similar to that reported by Forbes and Draper (1958). Tranquility was induced by intraperitoneal injection of Atarax,[3] 25 mg./lb. body weight, 2 hours prior to recording. The pig was suspended in a ventral position in a cloth sling, each leg immersed in a 10% sodium chloride solution contained in a galvanized steel beaker. The electrodes were immersed in the salt solution for recording with a Sanborn Cardiette.[4]

Twenty-four hours after recording the electrocardiograms, the four pigs were autopsied.[5] Heart and intestinal tissues were examined microscopically.

TABLE 1. COMPOSITION OF CONTROL RATION

Ingredients	Percent
Glucose	68.15
Casein [a]	23.00
Dicalcium phosphate	4.00
Iodized salt	0.50
Trace mineral mix [b]	0.20
Vitamin mix [c]	0.15
Antibiotic [d]	++
Corn oil	3.00
Wood flock	1.00

[a] Crude casein and vitamin-extracted casein used in experiments 1 and 2, respectively.
[b] Contained 296.9 gm. $MgCO_3$, 90.0 gm. $FeSO_4$, 27.2 gm. $MnSO_4 \cdot H_2O$, 9.0 gm. $CoCl_2 \cdot 6H_2O$, 9.0 gm. $CuSO_4$, 1.8 gm. NaF, 1.0 gm. KI and 18.7 gm. $ZnCO_3$ per pound.
[c] Contained 1 gm. thiamine-HCl, 2 gm. riboflavin, 12 gm. calcium pantothenate, 7 gm. nicotinic acid, 1.2 gm. folic acid, 1 gm. pyridoxine-HCl, 12 mg. vitamin B_{12}, 30 mg. biotin, 4 gm. P-amino benzoic acid, 42 gm. inositol, 400 mg. 2-methyl-1, 4-naphthoquinone, 7 gm. ascorbic acid, 340 gm. choline chloride, 2,150,000 I.U. vitamin A and 270,000 I.U. of vitamin D per pound.
[d] Supplied 25 mg. each of chlortetracycline and penicillin per pound of ration.

Results

Results of the two experiments are shown in tables 2 and 3. In experiment 1, growth

[1] Deceased.
[2] The authors wish to acknowledge Corn Products Co., New York, New York; Merck & Co., Rahway, New Jersey; American Cyanamid Co., Pearl River, New York; Illinois Farm Supply Co., Bloomington, Illinois and Moorman Mfg. Co., Quincy, Illinois for funds and products which made this study possible.

[3] Product of Chas. Pfizer & Co., Inc. Each cc contained 200 mg. of Hydroxyzine Hydrochloride with 10% N, N-Dimethylacetamide and 0.9% Benzyl alcohol as preservative.
[4] Lawrence D. Siler, Physical Environment Unit of the Graduate College, University of Illinois, made the electrocardiographic records.
[5] Autopsy performed by E. I. Pilchard, College of Veterinary Medicine, University of Illinois.

TABLE 2. THE EFFECT OF POTASSIUM LEVEL UPON PIG PERFORMANCE RESULTS OF EXPERIMENT 2

	Added levels (%) of potassium[a]						
	0	0.1	0.2	0.3	0.4	0.5	
Av. daily gain, lb.[b]							Av.
Rep. 1	0.08	0.17	0.55	0.68	0.60	0.61	0.45
Rep. 2	0.04	0.29	0.46	0.72	0.54	0.65	0.45
Av.	0.06	0.23	0.50	0.70	0.57	0.63	....
Gain per lb. feed, lb.							
Rep. 1	0.19	0.33	0.55	0.57	0.53	0.57	0.46
Rep. 2	0.08	0.41	0.50	0.61	0.57	0.60	0.46
Av.	0.14	0.37	0.52	0.59	0.55	0.58	....

[a] Control ration contained 0.027% potassium. Supplemental potassium supplied by K_2CO_3.
[b] Average initial weights for replicates 1 and 2 were 10.1 and 10.7, respectively. Each figure represents average performance of 4 pigs during the 35-day test period.

rate and gain per unit of feed increased up to and including a level of 0.3% added potassium. In experiment 2, performance improved up to the 0.25% supplemental level of potassium with higher levels showing no consistent advantage.

Statistical analyses, table 4, show that rate of gain and gain per pound of feed were significantly affected by potassium level.

Using the method of least squares with adjustment for differences of initial weight, estimates of the optimum level of supplemental potassium were 0.26% and 0.22% in experiments 1 and 2, respectively. As these values did not differ significantly, a pooled estimate, of 0.24% supplemental potassium, was calculated. Since the control rations for the two experiments contained an average of 0.015% potassium, the optimum level thus indicated for the young pig was approximately 0.26%.

Pigs on the control ration exhibited poor appetite, growth and feed efficiency from the beginning of each experiment. They developed rough hair coats, became emaciated, listless, weak and unsteady on their feet.

Representative electrocardiograms (ECG's) are shown in figure 1. ECG's for the deficient pigs (334S, 3391B) were distinctly different from those of their litter-mates (333B, 3396B). Assuming the latter pigs to be normal, pigs 334S and 3391B had abnormal cardiac function. The data in table 5 show that dietary potassium level markedly affected interval and amplitude of electrocardiographic waves.

Autopsy of the ECG pigs revealed no gross pathological symptoms. Microscopic examination of heart and intestinal tissue were negative for potassium deficiency lesions.

Discussion

The estimated optimum level of potassium for pigs weaned at 14 to 18 days is approximately 0.26% of the ration. This is similar to the 0.23 to 0.28% values of Meyer *et al.* (1950) for the 50-lb. pig. The latter animals consumed a daily average of 51.5 mg. of potassium per pound of body weight whereas

TABLE 3. THE EFFECT OF POTASSIUM LEVEL UPON PIG PERFORMANCE RESULTS OF EXPERIMENT 3

	Added levels (%) of potassium[a]								
	0.00	0.15	0.20	0.25	0.30	0.35	0.40	0.45	
Av. daily gain, lb.[b]									Av.
Rep. 1	0.01	0.20	0.40	0.45	0.36	0.45	0.42	0.39	0.34
Rep. 2	0.02	0.27	0.43	0.45	0.30	0.40	0.42	0.43	0.34
Av.	0.02	0.24	0.42	0.45	0.33	0.42	0.42	0.41	....
Gain per lb. feed, lb.									
Rep. 1	0.04	0.28	0.43	0.48	0.46	0.47	0.42	0.47	0.38
Rep. 2	0.06	0.30	0.44	0.42	0.35	0.52	0.51	0.42	0.38
Av.	0.05	0.29	0.44	0.45	0.40	0.50	0.46	0.44	....

[a] Control ration contained 0.004% potassium. Supplemental potassium supplied by K_2CO_3.
[b] Average initial weight for replicates 1 and 2 were 10.1 and 10.6 lb., respectively. Each figure represents average performance of 2 pigs for the 28-day test period.

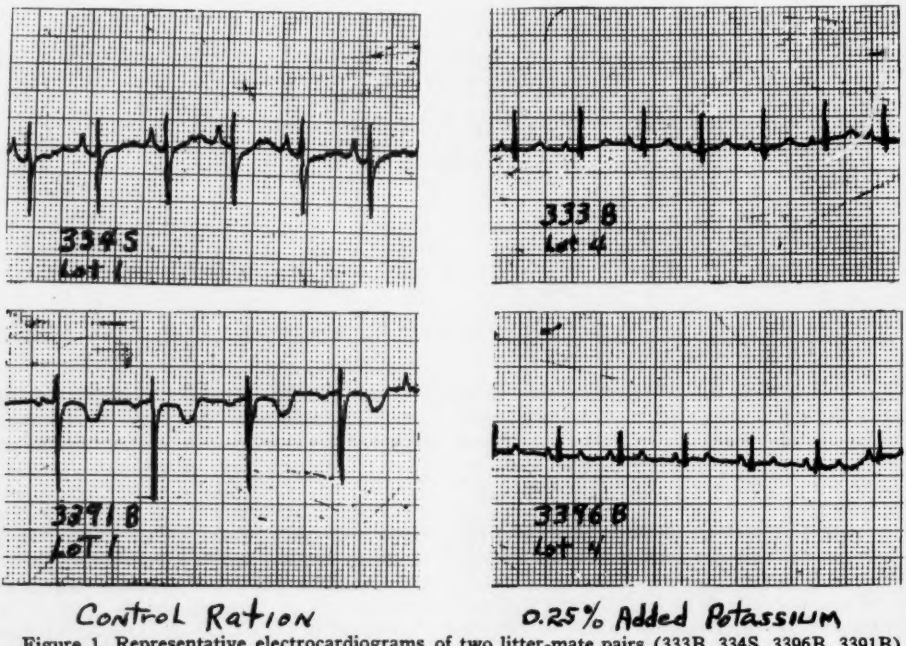


Figure 1. Representative electrocardiograms of two litter-mate pairs (333B, 334S, 3396B, 3391B) after 28 days on test.

TABLE 4. ANALYSES OF EXPERIMENTS 1 AND 2

Source	Mean square [a] d.f.	Gain	Mean square d.f.	Gain/lb. feed
Experiment 1				
Levels (L)	5	622.94**	5	0.0634***
Group pairs (G)	3	11.89	..	..
Replicates (R)+RG	4	1.61	1	0.0001
RL	5	15.52	5	0.0025
Error	29	6.20	..	..
Experiment 2				
Levels (L)	7	68.46**	7	0.0429**
Group pairs (G)	1	0.08	..	..
Replicates (R)+RG	2	8.82	1	0.0000
RL	7	1.27	7	0.0021
Error	13	7.22	..	..

[a] Covariance analysis with adjustment to equal initial weight.
** $P<0.01$.
*** $P<0.001$.

the pigs used in the current study consumed 60–70 mg. per pound of body weight.

This estimated optimum level of potassium would suggest little concern for deficiency in practical rations since natural feedstuffs are good sources of this element. However, in many semi-purified rations or rations containing ingredients in which potassium is not readily available supplementation is essential.

Within 5 or 6 days pigs on the control ration exhibited poor appetite. As the experiment progressed, slow growth was obvious and the pigs developed rough hair coats, became emaciated, less active, and unsteady on their feet. Two pigs died within a week after termination of the first experiment (35 days

TABLE 5. INTERVAL AND AMPLITUDE MEASUREMENT OF ECG WAVES

Pig no.	Potassium added, %	Wave interval, seconds PR	QRS	QT	Wave amplitude, millivolts P	R	T	S	Heart beat per min.
333B	.25	.14	.025	.18	.15	.70	.12	—.20	129
3396B	.25	.09	.026	.16	.16	.61	.13	—.05	126
Av.	...	.11	.025	.17	.15	.65	.12	—.12	127
334S	.00	.11	.04	.36	.30	.65	.20	—1.05	120
3391B	.00	.12	.04	.23	.25	.44	.22	—1.66	93
Av.	...	.11	.04	.29	.27	.54	.21	—1.35	106

in length). The remaining six deficient pigs were given access to a potassium-adequate ration and recovery, as judged by appearance, growth rate and feed efficiency, was complete within 3 weeks.

Abnormal cardiac activity was associated with potassium deficiency as shown by electrocardiograms (ECG). This characteristic has previously been reported for the calf (Sykes and Alfredson, 1940) and the chick (Sturkie, 1950). With the latter, ECG:abnormality was detected in both 2-day and 42-day old chicks within 10 days after being placed on a potassium-deficient ration. However, at autopsy no gross lesions of the heart were detected.

In this report, the pigs had been on test 28 days prior to recording the ECG's. Hence, the sensitivity of this technique for measuring the initial potassium-deficiency-induced cardiac malfunction cannot be stated. However, it seems worthy of further evaluation since autopsy of deficient pigs revealed neither gross organ anomalies nor cellular lesions as determined by microscopic examination of heart and intestinal tissues.

Summary

Two experiments involving 80 pigs were conducted to study the effect of levels of dietary potassium on pigs weaned directly to dry rations at 14 to 18 days of age. The control rations analyzed 0.027% and 0.004% potassium. Potassium was added as K_2CO_3 in increments of 0.1% and 0.05% in experiments 1 and 2, respectively.

Pigs on the control rations had poor appetite, became emaciated, had rough hair coats, became unsteady on their feet, with death occurring after 6 weeks. Electrocardiograms indicated marked cardiac impairment but autopsy revealed no pathological symptoms directly attributable to the potassium deficiency.

The optimum total level of potassium was estimated to be approximately 0.26%.

Literature Cited

Forbes, R. M. and H. H. Draper. 1958. Production and study of vitamin E deficiency in the baby pig. J. Nutr. 65:535.

Hughes, E. H. and N. R. Ittner. 1942. The potassium requirement of growing pigs. J. Agr. Res. 64:189.

Meyer, J. H., R. H. Grummer, P. H. Phillips and G. Bohstedt. 1950. Sodium, chlorine and potassium requirements of growing pigs. J. Animal Sci. 9:300.

Sykes, J. F. and A. V. Alfredson. 1940. Studies on the bovine electrocardiogram. I. Electrocardiographic changes in calves on low potasium rations. Proc. Exp. Biol. and Med. 43:575.

Sturkie, P. D. 1950. Abnormal electrocardiograms of chickens produced by potassium deficiency and the effects of certain drugs on the abnormalities. Amer. J. Physiol. 162:538.

EFFECT OF FOUR MATURITY STAGES OF TIMOTHY HAY ON ITS CHEMICAL COMPOSITION, NUTRIENT DIGESTIBILITY AND NUTRITIVE VALUE INDEX [1]

L. E. Lloyd, H. F. M. Jeffers, E. Donefer and E. W. Crampton

Macdonald College [2] (McGill University), Canada

ONE of the important factors influencing the feeding value of a forage is its stage of maturity at time of harvesting. As a result of investigations carried out over a number of years, it is an accepted fact that a forage decreases in overall nutritive value with increasing maturity. It is also well-known that this decrease is due, in great part, to a decrease in the nutrient content of the forage together with a concomitant increase in the fibrous components and general lignification. The combined effect of these latter changes invariably has been a reduction in nutrient digestibility. More recently, a decrease in voluntary forage intake has been shown to be associated with advancing maturity.

In an application of the Nutritive Value Index (N.V.I.), as proposed by Crampton *et al.* (1960), to a study of the effect of species, physical form and maturity stage on overall forage feeding value, Lloyd *et al.* (1960) fed red clover *(Trifolium pratense)* and timothy *(Phleum pratense)* hays each harvested at an "early" and "late" stage of maturity. A slight reduction in both intake and energy digestibility with advancing maturity contributed to a decrease in the N.V.I.'s of the forages.

Because only two maturity stages, involving a cutting interval of 23 days, were examined by Lloyd *et al.* (1960), it was considered desirable to study in more detail the effect of the stage of maturity of a forage on its composition, nutrient digestibility, voluntary intake and thus N.V.I. The research to be reported, in which four maturity stages of timothy hay were fed to sheep, was designed to provide this more detailed information.

Experimental

A 4 x 4 Latin square design was used. Four Cheviot ewes were confined to digestion cages and were each fed in a different rotation, as a complete ration, ground timothy hay [3] which had been harvested at four stages of maturity and cured artificially. Details of the forages harvested are given in table 1. Free access to water and cobalt-iodized salt was available, and sufficient forage was provided each day to ensure an excess of at least 10% over the previous day's intake.

TABLE 1. HARVESTING DATE, CUTTING INTERVALS AND CLASSIFICATION OF THE FOUR MATURITY STAGES OF TIMOTHY HAY

Maturity Stage	Date harvested	Cutting interval	Classification
		days	
No. 1	17 June, 1958	..	Early bloom
No. 2	2 July, 1958	15	Half bloom
No. 3	29 July, 1958	27	Full bloom
No. 4	12 Aug., 1958	14	Post bloom

The feeding periods were of 21 days duration. Average daily voluntary forage intake was measured over the last 10 days of each period. The final 10 days constituted the collection period for the digestibility studies. Feces collected on days 12 through 21 were apportioned to forage consumed on days 10 through 19. Uneaten forage was recovered daily, weighed and discarded.

All chemical analyses were by A.O.A.C. (1955) methods except for lignin which was determined by the method of Sullivan (1959), and cellulose which was determined using a modification of the method of Crampton and Maynard (1938) described by Donefer *et al.* (1960). Gross energy was determined on all samples using a Parr oxygen bomb calorimeter.

The method of Donefer *et al.* (1960) was used to determine *in vitro* cellulose digestion.

Results and Discussion

The chemical composition of the four maturity stages of timothy hay is given in

[1] Macdonald College Pasture Committee Series No. XXXV. This research was assisted financially by the Quebec Agricultural Research Council.

[2] Department of Animal Science.

[3] Ground by means of a hammer mill fitted with a ¼-inch screen.

TABLE 2. CHEMICAL COMPOSITION OF TIMOTHY HAY HARVESTED AT FOUR STAGES OF MATURITY

Chemical component % of forage D.M.	Maturity stage No. 1 (early bloom)	No. 2 (half bloom)	No. 3 (full bloom)	No. 4 (post bloom)
Crude protein (%)	10.0	8.1	6.3	5.9
Crude fiber (%)	27.8	30.3	31.5	33.2
Ether extract (%)	1.9	1.4	1.3	1.1
N-free extract (%)	53.7	54.4	55.6	54.1
Ash (%)	6.6	5.8	5.3	5.7
Cellulose (%)	31.0	33.5	32.8	34.0
Lignin (%)	5.3	7.4	9.7	10.1
Gross energy (Cal./gm.)	4.40	4.39	4.44	4.41

table 2. The steady decrease in crude protein and increase in crude fiber content with advancing maturity was in accordance with the findings of others working with various forage species. Similar changes with maturity were observed by Hosterman and Hall (1938) and Waite and Sastry (1949) for timothy, by Phillips *et al.* (1954) for 8 different grasses, and by Meyer *et al.* (1957) for oat forage and by Weir *et al.* (1960) for alfalfa. The observed decrease in the ether extract and ash content of the timothy hay with increasing maturity was in agreement with the findings of Phillips *et al.* (1954) working with eight grasses and of Bratzler *et al.* (1959) working with orchard grass. Waite and Sastry (1949) observed a decrease in the ether-extractable material of a pure timothy sward with advancing maturity.

The cellulose content of timothy hay showed a tendency to increase with maturity, but the overall change from the early bloom through the post bloom stage was not of great magnitude. Norman (1936) stated that the "natural" cellulose of perennial rye grass increased as maturity approached, while Patton and Gieseker (1942) and Patton (1943) obtained similar results with different Montana grasses. In their study of eight grasses, Phillips *et al.* (1954) found that all increased in both "true" and "natural" cellulose up to the flowering stage, and in some grasses the increase continued to the seed-dough stage.

The marked increase in lignin content of the timothy hay, particularly to the full bloom stage, is noteworthy. This observation is also compatible with the findings of others. A similar increase was noted by Norman (1936) in rye grass, by Patton and Gieseker (1942) and Patton (1943) in various Montana grasses and by Louw (1941) in South African grasses. Armstrong *et al.* (1950), studying seven herbage species including grasses, legumes and herbs, stated that in a majority of the species examined, a marked rise in lignin content was found to occur at the flowering stage. Steppler (1951) observed an increase in the percent lignified material with advancing maturity in timothy and bromegrass, the rate of increase being slower once the seeds started to form. Using oat forage cut at seven stages of maturity, Meyer *et al.* (1957) indicated that lignin content increased steadily during the growing period until the milk stage. Working with alfalfa, Meyer *et al.* (1960) and Weir *et al.* (1960) found that lignin increased with advancing maturity, with the latter group rating a stabilization of lignin content during the different bloom stages.

It is of interest to note the lack of change in the content of nitrogen-free extract or in the gross energy value of timothy hay with advancing maturity.

The upward trend in the lignin, crude fiber and cellulose content of timothy hay as maturity is reached and the concomitant downward trend in protein, ether extract and ash content indicated the probability of the existence of close relationship between these various forage components. Table 3 shows

TABLE 3. SIMPLE CORRELATION COEFFICIENTS BETWEEN CERTAIN COMPONENTS OF TIMOTHY HAY HARVESTED AT FOUR STAGES OF MATURITY

Chemical components	Simple correlation coefficient (r)
% Protein and % lignin	−.91**
% Protein and % cellulose	−.75**
% Protein and % crude fiber	−.80**
% Protein and % ash	0.81**
% Lignin and % cellulose	0.57*
% Lignin and % crude fiber	0.70**
% Lignin and % ash	−.69**
% Cellulose and % crude fiber	0.82**
% Cellulose and % ash	−.67**
% Crude fiber and % ash	−.62**

* Significantly different from zero ($P<0.05$).
** Significantly different from zero ($P<0.01$).

simple correlation coefficients between these forage fractions and indicates the high degree of relationship between certain observations.

The mean apparent digestion coefficients for various fractions of the four maturity stages of timothy hay are given in Table 4. It may be noted that, in general, there was a decrease in the apparent digestibility of all fractions with advancing maturity.

The apparent digestibility of the dry matter of timothy hay declined steadily to the full bloom stage, after which the change was less marked. Decreases in the digestibility of either dry or organic matter with increased maturity of either grazed or cured forages have been noted also by Crampton and Forshaw (1939), Crampton and Jackson (1944), Forbes and Garrigus (1950), Schneider *et al.* (1953), Jones *et al.* (1959), Reid *et al.* (1959), Martz *et al.* (1960) and Weir *et al.* (1960).

The steady decline in the apparent digestibility of crude protein through each maturity stage was probably a combined effect of increasing lignification and decreased content of this nutrient in the forage. Similar decreases in protein digestibility with increasing maturity have been pointed out by Crampton and Forshaw (1939), Meyer *et al.* (1957), Reid *et al.* (1959), Martz *et al.* (1960) and Weir *et al.* (1960).

The apparent digestibility of the carbohydrate fractions (i.e. crude fiber, cellulose and nitrogen-free extract) declined progressively to the full bloom stage (No. 3), after which there was no significant change. Crampton and Forshaw (1939) observed a drop in the digestibility of the crude fiber of pasture herbage with maturity, while Louw (1941) indicated that the digestibility of natural cellulose of mature grasses was lower than that of more immature grasses. A fall in the apparent digestibility of the ether extract in timothy hay was observed only at the post bloom stage.

The progressive decline in the apparent digestibility of the gross energy of maturing timothy hay was in accordance with the observations of others on the effect of increasing forage maturity on the digestibility of this entity (Schneider *et al.*, 1953; Meyer *et al.*, 1957; Andersen *et al.*, 1959; Davis and Decker, 1959; Martz *et al.*, 1960; Weir *et al.*, 1960).

It is of interest to note the close relationship between the digestibility of dry matter and gross energy—a relationship that was expected and that has been observed widely in forage digestion studies. In addition, it may be noted that, although the crude fiber and cellulose contents of each maturity stage of forage were not similar quantitatively (table 2), their digestion coefficients did not differ appreciably.

TABLE 4. MEAN APPARENT DIGESTION COEFFICIENTS FOR VARIOUS FRACTIONS OF TIMOTHY HAY HARVESTED AT FOUR STAGES OF MATURITY

	Apparent digestion coefficients (%)			
	Maturity stage No. 1 (early bloom)	Maturity stage No. 2 (half bloom)	Maturity stage No. 3 (full bloom)	Maturity stage No. 4 (post bloom)
Dry matter	65	57	51	48
Crude protein	61	55	44	32
Crude fiber	65	52	46	46
Cellulose	65	56	48	47
N-free extract	70	64	57	55
Ether extract	48	46	45	27
Gross energy	65	56	51	47

The rate of the *in vitro* cellulose digestion of the four maturity stages of timothy hay is shown in figure 1. In the report of Donefer *et al.* (1960), it was pointed out that lag periods in the start of *in vitro* cellulose digestion appeared to be related to the nutritive value of the forage species studied. In the present trials, where only one species was examined, increasing lag periods, although of relatively small magnitude, appeared to be related to increasing maturity of the timothy hay. As with the various forage species studied by Donefer *et al.* (1960), the cellulose of each maturity stage of timothy hay was digested *in vitro* at an increasing rate to 12 hours, after which there was a decline in the rate of digestion. It is of interest that at each fermentation time, there was a drop in *in vitro* cellulose digestion with increasing maturity stage. Working with orchardgrass,

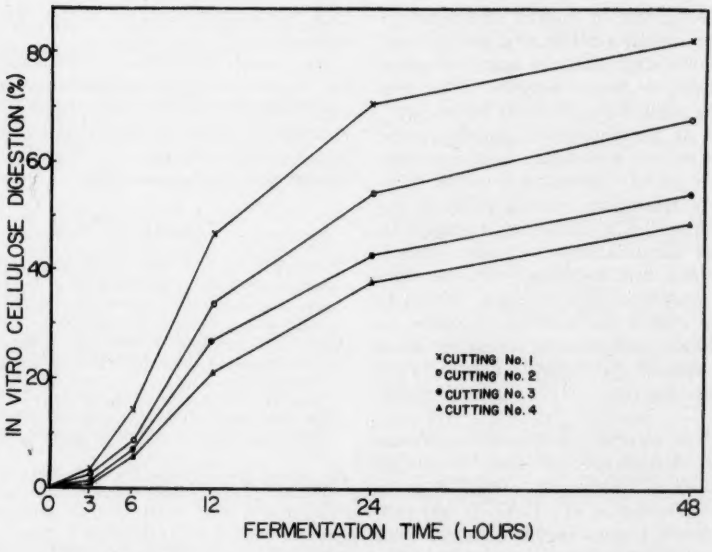


Figure 1. Rate of in vitro cellulose digestion of timothy hay harvested at four stages of maturity.

alfalfa, timothy and bromegrass, the Ohio group (Kamstra *et al.*, 1958, and Quicke and Bentley, 1959) have also found that *in vitro* cellulose digestibility decreases with advancing maturity.

The effect of stage of maturity of timothy hay on voluntary intake, energy digestibility and hence the Nutritive Value Index (N.V.I.) is presented in summary form in table 5. The observed decrease in daily voluntary forage intake (and thus in relative intake) with advancing maturity was not unexpected in view of similar findings with this and other forage species by Forbes and Garrigus (1950), Schneider *et al.* (1953), Smith *et al.* (1958), Davis and Decker (1959) and Reid *et al.* (1959).

It may also be seen in table 5 that the nutritional value of timothy hay, as measured by the N.V.I., declined significantly with the advance in stage of maturity of the forage. This confirms the findings of Lloyd *et al.* (1960) who observed that a slight reduction in both intake and energy digestibility with advancing maturity (two maturity stages of red clover and timothy hays) contributed to a significant decrease in the N.V.I. of the forages.

It should be pointed out that, when one species of forage is being evaluated, differ-

TABLE 5. THE EFFECT OF STAGE OF MATURITY ON THE INTAKE, GROSS ENERGY DIGESTIBILITY AND NUTRITIVE VALUE INDEX OF TIMOTHY HAY WHEN FED TO SHEEP

	In vivo determinations[a]			
Maturity stage	Average daily voluntary dry matter intake	Relative intake[b]	Apparent digestibility of gross energy	Nutritive Value Index[b]
	gm	%	%	
No. 1	1593	115	65	75
No. 2	1487	108	56	60
No. 3	1242	90	51	46
No. 4	1079	78	47	37

[a] Each value represents the mean of four observations.
[b] For calculation of Relative intake and Nutritive Value Index, see Crampton *et al.* (1960).

ences in the content of various chemical entities between samples within that species may be highly correlated with the nutritive value of the individual forage samples. This was shown in the present report where such chemical entities as percent crude protein, crude fiber, ether extract and lignin in the various maturity stages of timothy hay were obviously closely related to feeding value as expressed by the N.V.I. However, it should be realized that this relationship between chemical composition and nutritive value becomes much less apparent, and in many instances non-existent, when an attempt is made to compare forage samples representing more than one species (Kamstra *et al.*, 1958; Quicke and Bentley, 1959; and Kivimäe, 1960).

The N.V.I. system of describing forage quality as determined in *in vivo* trials (Crampton *et al.*, 1960) or predicted in *in vitro* tests (Donefer *et al.*, 1960) is not subject to between-species inconsistencies, since it measures the total digestible energy potential of a forage independent of species consideration.

Summary

Timothy (*Phleum pratense*) hay was harvested at four stages of maturity and fed to sheep in order to determine the effect of forage maturity on nutrient digestibility and overall feeding value as measured by the Nutritive Value Index. Each maturity stage was also analyzed chemically.

With advancing maturity in timothy hay from the early-bloom through the post-bloom stages, a downward trend in protein, ether extract and ash content was accompanied by an upward trend in the content of crude fiber, cellulose and lignin. There was no evidence of a change in the content of nitrogen-free extract or in the gross energy value of timothy hay with advancing maturity.

In general, there was a decrease in the apparent digestibility of all fractions of timothy hay with increasing maturity. The digestibility of gross energy and crude protein fell progressively through all maturity stages. The digestibility of dry matter, crude fiber, cellulose and nitrogen-free extract declined progressively to the full-bloom stage after which there was no significant change. Ether extract digestibility decreased only at the post-bloom stage.

In vitro cellulose digestion decreased with each advancing maturity stage of timothy hay.

As a result of substantial decreases in both the intake and energy digestibility of timothy hay through each maturity stage, its overall nutritional value, as measured by the Nutritive Value Index, was significantly decreased as maturity was approached.

Literature Cited

Andersen, P. E., J. T. Reid, M. J. Anderson and J. W. Stroud. 1959. Influence and level of intake upon the apparent digestibility of forages and mixed diets by ruminants. J. Animal Sci. 18:1299.

A.O.A.C. 1955. Official Methods of Analysis (8th ed.) Association of Official Agricultural Chemists, Washington 4, D.C.

Armstrong, D. G., H. Cook and B. Thomas. 1950. The lignin and cellulose contents of certain grassland species at different stages of growth. J. Agr. Sci. 40:93.

Bratzler, J. W., E. Keck, Jr., L. F. Marriott and J. B. Washko. 1959. Nutritive value of orchard grass as affected by level of nitrogen fertilization and stage of maturity. J. Dairy Sci. 42:934.

Crampton, E. W. and R. P. Forshaw. 1939. Pasture Studies XV. The intra-seasonal changes in the nutritive value of pasture herbage. Sci. Agr. 19:701.

Crampton, E. W., E. Donefer and L. E. Lloyd. 1960. A Nutritive Value Index for forages. J. Animal Sci. 19:538.

Crampton, E. W. and I. R. C. Jackson. 1944. Seasonal variation in chemical composition of pasture herbage and the relation to its digestibility by steers and sheep. Pasture Studies XXVI. J. Animal Sci. 3:333.

Crampton, E. W. and L. A. Maynard. 1938. The relation of cellulose and lignin content to nutritive value of animal feeds. J. Nutr. 15:383.

Davis, R. F. and A. M. Decker. 1959. Yield and value of forages for milk production as affected by stage of maturity. Grasslands, p. 225. Publication No. 53 of the A.A.A.S.

Donefer, E., E. W. Crampton and L. E. Lloyd. 1960. Prediction of the Nutritive Value Index of a forage from *in vitro* rumen fermentation data. J. Animal Sci. 19:545.

Forbes, R. M. and W. P. Garrigus. 1950. Some relationships between chemical composition, nutritive value and intake of forages grazed by steers and wethers. J. Animal Sci. 9:354.

Hosterman, W. H. and W. L. Hall. 1938. Time of cutting timothy: Effect on the proportion of leaf blades, leaf sheaths, stems, and heads and on their crude protein, ether extract and crude fiber contents. J. Am. Soc. Agron. 30:564.

Jones, J. R., D. E. Hogue and G. L. Hunt. 1959. Effects of date and method of harvesting of mixed hay on the performance of fattening lambs. J. Animal Sci. 18:1539.

Kamstra, L. D., A. L. Moxon and O. G. Bentley. 1958. The effect of stage of maturity and lignification on the digestion of cellulose in forage plants by rumen microorganisms *in vitro*. J. Animal Sci. 17:199.

Kivimäe, A. 1960. Estimation of the digestibility of grassland crops from their chemical composition. Paper 2B–3 of the 8th International Grasslands Congress. Proceedings in press.

Lloyd, L. E., E. W. Crampton, E. Donefer and S. E.

Beacom. 1960. The effect of chopping versus grinding on the nutritive value index of early versus late cut red clover and timothy hays. J. Animal Sci. 19:859.

Louw, J. G. 1941. The relative digestibility of the constituents of the carbohydrate complex of grasses at successive stages of growth with reference to their partition into crude fiber and nitrogen-free extract according to the standard method of feeding-stuff analysis. Onderstepoort J. Vet. Sci. Animal Ind. 17:165.

Martz, F. A., C. H. Noller and D. L. Hill. 1960. Apparent digestibility of alfalfa-brome-grass with advancing maturity, using a modified digestion trial. J. Dairy Sci. 43:868.

Meyer, J. H., W. C. Weir, L. G. Jones and J. L. Hill. 1957. The influence of stage of maturity on the feeding value of oat hay. J. Animal Sci. 16:623.

Meyer, J. H., W. C. Weir, L. G. Jones and J. L. Hill. 1960. Effect of stage of maturity, dehydrating versus field-curing and pelleting on alfalfa hay quality as measured by lamb gains. J. Animal Sci. 19:283.

Norman, A. G. 1936. The composition of forage crops. I. Rye grass (Western Wolths) Biochem. J. 30: 1354.

Patton, A. R. 1943. Seasonal changes in the lignin and cellulose content of some Montana grasses. II. J. Animal Sci. 2:59.

Patton, A. R. and L. Gieseker. 1942. Seasonal changes in the lignin and cellulose content of some Montana grasses. J. Animal Sci. 1:22.

Phillips, T. G., J. T. Sullivan, M. E. Loughlin and V. G. Sprague. 1954. Chemical composition of some forage grasses. I. Changes with plant maturity. J. Am. Soc. Agron. 46:361.

Quicke, G. V. and O. G. Bentley. 1959. Lignin and methoxyl groups as related to the decreased digestibility of mature forages. J. Animal Sci. 18:365.

Reid, J. T., W. K. Kennedy, K. L. Turk, S. T. Slack, G. W. Trimberger and R. P. Murphy. 1959. Effect of growth stage, chemical composition, and physical properties upon the nutritive value of forages. J. Dairy Sci. 42:567.

Schneider, B. H., B. K. Soni and W. E. Ham. 1953. Digestibility and consumption of pasture forage by grazing sheep. J. Animal Sci. 12:722.

Smith, J. C., R. W. Hemken, R. F. Davis and A. M. Decker. 1958. The nutritive value of alfalfa hay harvested at three stages of maturity. J. Animal Sci. 17:1209.

Steppler, H. A. 1951. Pasture Studies XXXI. Lignification studies with various grass species. Sci. Agr. 31:1.

Sullivan, J. T. 1959. A rapid method for the determination of acid-insoluble lignin in forages and its relation to digestibility. J. Animal Sci. 18:1292.

Waite, R. and K. N. S. Sastry. 1949. The composition of timothy (Pheleum pratense) and some other grasses during seasonal growth. Emp. J. Exp. Agr. 17:179.

Weir, W. C., L. G. Jones and J. H. Meyer. 1960. Effect of cutting interval and stage of maturity on the digestibility and yield of alfalfa. J. Animal Sci. 19:5.

STUDIES ON BOVINE OCULAR SQUAMOUS CARCINOMA ("CANCER EYE") XI. EFFECTS OF SUNLIGHT

DAVID E. ANDERSON [1] AND PHILIP E. SKINNER [2]

The University of Texas M.D. Anderson Hospital and Tumor Institute, Houston

A STATEMENT frequently seen in the literature on bovine eye cancer is to the effect that the disease is more prevalent in the Southwest and West than elsewhere in the United States (Guilbert *et al.*, 1948; Knox, 1949; see Russell *et al.*, 1956, for additional references). The prevalence is usually attributed to high insolation, though direct support for this has never been offered. Sunlight could be a factor because it has been used frequently and with success to induce skin cancer in laboratory animals. A historical review and full discussion of carcinogenesis by ultraviolet light is given by Blum (1959). These studies and those utilizing radiation from artificial sources have shown that the carcinogenic response is not elicited by the entire spectrum of sunlight, but rather is confined to wavelengths ranging from 2800 to 3200 ångstroms in the ultraviolet spectrum. Obviously, skin cancer has not been experimentally induced in man, but clinical evidence strongly favors the hypothesis that the ultraviolet component of sunlight is a causative agent for the following reasons: (1) the carcinogenic spectrum in mice elicits an erythemic response in man, the severity of which increases with prolonged exposure; (2) skin cancer is most prevalent in parts of the earth where sunlight is intense; (3) it is more prevalent in parts of the body exposed to sunlight than in unexposed parts; (4) it is more prevalent in light- than in dark-skinned peoples; and (5) the type of tumor observed in man compared to the type induced in laboratory animals is readily explained in terms of a difference in the penetration of radiation.

[1] Department of Biology. This is publication No. 11 of the Cancer Eye Study Section. The investigation was supported by Grant C-2890 from the National Cancer Institute of the National Institutes of Health, Public Health Service. The authors wish to express their appreciation and gratitude to Doyle Chambers, Oklahoma State University, for his suggestions during the study; and to Jay L. Lush, Iowa State University, for his valuable criticisms and suggestions during the preparation of the manuscript. Appreciation is expressed to personnel of the California, Montana, Nevada, New Mexico, Oregon, and South Dakota State Agricultural Experiment Stations and of the Animal Husbandry Research Division, U.S. Department of Agriculture, for making cattle and records available. Appreciation is also expressed to the Turner Ranch, Sulphur, Oklahoma for placing their records at our disposal.

[2] Deceased.

Materials and Methods

A survey of cattle was conducted between 1957 and 1959 to provide information on the relationship between sunlight and eye cancer (squamous cell carcinoma), and to provide genetic information on susceptibility. The routine in each herd consisted of examining and photographing the eyes of all animals of breeding age and utilizing herd records for pedigree and age information. In nine of the herds, eight of which were experiment station herds, disposal records were also available showing which animals had been removed because of "cancer eye". This disposal material forms the basis of the present study.

Records complete enough for analysis were available on 4,960 female Herefords born between 1926 and 1954. Ages at disposal ranged from 2½ to 18 years. Those below 2½ years of age were not included because the disorder is infrequent at young ages and the records were incomplete in some cases. Other than the age factor, the animals or herds were not selected in any way except on the basis of having records showing age and reason for disposal. Eye pigmentation was not recorded in these data. No record was considered to refer to "cancer eye" unless it definitely listed this or some related term as the reason for disposal, regardless of the animal's prior eye health history. The accuracy of diagnoses based on disposal records is lower than the 99% for clinical diagnoses (Wynne, unpublished data, 1958), but it is still probably at least 80%, and more likely than not, 90%.

The age distributions differed widely among the herds, some disposing of more animals at relatively young ages, while others retained more to older ages when the disease is most prevalent. Since wide differences in age could influence the incidence rates, age was controlled here by the "direct" method, making every age distribution identical with that of a standard population (Pearl, 1940). The age distribution of the largest herd was used as the standard because it covered the period of observation of most other herds; however, any

other herd or theoretical herd would have served the same purpose.

It was not possible to measure directly the incidence of ultraviolet radiation in sunlight for present purposes, but it was possible to utilize criteria of sunlight which reflect differences in this radiation; for example, latitude, average annual hours of sunshine,[3] and altitude. With regard to latitude, the annual incidence of ultraviolet radiation is more intense in the lower latitudes or southern portions of the United States than in higher latitudes (Blum, 1959. This distribution is determined by factors beyond the scope of this report, but stratospheric ozone, and the angle of the sun's rays from zenith are involved, both of which vary with time of day and season. Average annual hours of sunshine is influenced by many of these same factors. The association between altitude and ultraviolet radiation is due largely to the distribution of such filtering and dispersing factors as dust, smoke, and haze, which are not generally found in high altitudes.

The association between sunlight and eye cancer was studied by pooling herds into low, medium, and high levels of sunlight as measured by latitude, annual hours of sunshine, or altitude, and then comparing the frequency of eye cancer (at disposal) among these levels. For annual hours of sunshine, the low level consisted of the three herds with the three lowest averages; the medium level consisted of the next three herds; and the high level consisted of the three herds with the highest averages. The same procedure was used for the other two criteria, remembering that low latitudes tend to have high levels of sunlight. The restriction of three herds per level avoided any arbitrariness in assigning the herds, since only one grouping was possible. The groupings for annual hours of sunshine and for latitude were highly similar, seven of the nine herds being in common in corresponding levels of sunlight. The groupings for altitude and latitude were entirely different, and altitude and hours of sunshine had only one herd in common in one of the levels. These similarities or dissimilarities in groupings indicate that in these data hours of sunshine and latitude as criteria of sunlight are highly correlated, but each in turn is unrelated to altitude.

TABLE 1. ASSOCIATIONS BETWEEN "CANCER EYE" AND THREE CRITERIA OF SUNLIGHT

Criterion	Level of sunlight[a]	No. animals	Incidence[b]	Averages[c] within each level		
				Latitude	Sunshine	Altitude
			%	degrees	hr.	ft.
Latitude	Low	3445	3.6±0.3	46.4	2593	2466
	Med.	361	7.8±1.4	43.4	2840	3484
	High	1154	9.2±0.8	33.6	3150	2364
Hours of sunshine	Low	3445	3.6±0.3	46.4	2593	2466
	Med.	823	5.6±0.8	38.1	2800	2106
	High	692	11.7±1.2	33.4	3400	3256
Altitude	Low	670	4.8±0.8	36.1	2880	1087
	Med.	3909	5.1±0.1	44.4	2718	2580
	High	381	9.7±1.5	43.9	2704	4368

[a] Level refers to sunlight as measured by each criterion. Remember that low latitudes tend to have high levels of sunlight because this is the area near the equator.
[b] Age-adjusted.
[c] Weighted by number of animals in each herd comprising a level.

This method of pooling to form levels probably minimizes the effects of confounding of environmental differences with differences in management, diagnostic procedure, or genetic background that might result if the individual herd values had been used as in a regression or correlation analysis. Pooling also reduces sampling variation arising from small numbers of animals in some herds. Pooling may not extract all available information in these data, but it will detect any close relation between two variables.

Results

The association between the age-adjusted frequencies of eye cancer and three criteria of sunlight are given in table 1. Incidence increases with an increase in level of sunlight whether measured by latitude, annual hours

[3] Given as an isogram in Psoralens in Radiant Energy. J. Invest. Derm. 32:132, 1959. (Supplement to Feb. 1959 issue). It refers to the total number of hours of actual sunshine from sunrise to sunset per year and averaged over a 25-year period.

of sunshine, or altitude. These associations are unmistakably significant statistically, as is shown by the following chi-square and probability values, each of which is based on two degrees of freedom:

Latitude	$\chi^2=59.5, P<10^{-6}$
Hours sunshine	$\chi^2=79.2, P<10^{-6}$
Altitude	$\chi^2=14.1, P<.0009$

The increase in incidence from 3.6 to 9.2% for latitude coincides with a decrease in average latitude from 46.4° to 33.6°, and an increase in annual hours of sunshine from 2593 to 3150 hours. The disease thus appears to be more prevalent nearer the equator than farther away. This range in latitude is larger than the range in Dorn's (1944) study of human skin cancer, where the range was shown by Blum (1959) to be sufficient to reflect differences in ultraviolet radiation. French (1959) reported that 29 Herefords transferred from a latitude of 30° 30′ S to a latitude of 23° 30′ S (nearer the equator) exhibited an incidence of cancer and precursor lesions as high as or higher than that of locally bred Herefords, while the incidence in resident cattle at the former location was nil. It was not stated whether this difference was the result of a difference in exposure to sunlight or was merely the result of an age difference in the two general groups of cattle.

The increase in incidence from 3.6 to 11.7% for annual hours of sunshine involves all measures to some extent since average latitude shows a decrease, annual hours of sunshine a pronounced increase, and altitude an increase between the medium and high levels. The similarity in results between latitude and annual hours of sunshine is expected, owing to the similarity in the measures previously mentioned. A proportionality between the differences in incidence and in hours of sunshine is evident. For example, the 2.0% difference in incidence between the medium and low levels of sunshine corresponds to 200 more hours of sunshine; and the difference of 6.1% between the medium and high levels corresponds to a difference of 600 hours. Thus, an increase of 100 annual hours of sunshine is associated with approximately a 1.0% increase in incidence; however, since other factors could have contributed to the differences, the comparisons show only the regression of incidence on annual hours of sunshine and may not indicate a direct effect.

The incidence increase from 4.8 to 9.7% for altitude coincides with an increase in average altitude itself. Annual hours of sunshine and latitude are practically independent of altitude in these data, indicating that this increase cannot be explained by the confounding of altitude with the other two measures. The extent to which effects of scattered or reflected radiation possibly resulting from snow may have contributed to the high incidence values at high altitudes is not known. This source of indirect radiation was not measurable. Black (1934) investigated the distribution of the disease with respect to altitude and found no marked differences in incidence for altitudes from 3000–9000 feet, although he did mention that the incidence was highest at 8000–9000 feet. No incidence values were given and apparently no adjustments for differences in age were made.

The average age at disposal because of "cancer eye" was 7.8 years in the high levels of sunlight; 7.9 years in the medium; and 8.2 years in the low. These differences in age are small, but interesting, because they suggest in a different way that a high level of sunlight appears to increase the probability that a susceptible animal will develop the disease, and thereby become subject to disposal.

Discussion

The results just presented show disposals for "cancer eye" to occur more frequently and at a slightly earlier age in areas characterized by high levels of sunlight than in areas having lower levels, whether sunlight is measured by latitude, annual hours of sunshine, or altitude. These results thus favor the hypothesis that ultraviolet light is a factor contributing to the development of cancer of the eye in the bovine. Other contributing factors include high levels of nutrition, genetic differences, and lack of eyelid pigmentation according to Anderson (1960a,b); and possibly a viral agent according to Sykes *et al.* (1961).

That pigment is a factor affords additional evidence in support of present findings. Pigment, whether it is in the skin of the body or skin of the eyelids, has been shown to have a significant protective influence against the development of skin cancer, (Guilbert *et al.*, 1948; Bonsma, 1949; Rice, 1949; Anderson *et al.*, 1957; French, 1959; and Anderson, 1960a). In man, skin cancer is most prevalent in parts of the body exposed to sunlight, and is more prevalent in light- than in dark-

skinned peoples, according to Blum (1959). He reported that the mechanism by which pigment affords this protection appears to depend upon the ability of pigment granules to disperse or scatter incident radiation.

Further evidence pointing to an effect of sunlight, though more speculative, but still worthy of consideration, is the type and location of the tumor developing in the eye and its adnexa. Russell *et al.* (1956), in a histopathological study of 830 eyes selected by meat inspectors as having cancer of the eye or benign precursor lesions, found 735 tumors of squamous origin, three tumors of other cell types, and 92 eyes with inflammatory reactions, ulcer, or traumatic injury. Thus, of actual tumors 99.6% were of squamous origin. Although this estimate may be biased upwards because of the method of selection involved, it is still indicative of the rarity of basal cell carcinomas in the bovine. In man with thinner skin, cancer frequently involves the basal cell layer; while in the mouse, with even thinner skin, cancers are largely nonepithelial in origin. These differences in cell type could reflect a difference in the penetration of radiation from sunlight.

That the squamous cell lesions in the bovine have a marked predilection for developing on the medial and lateral parts of the eyeball which are not generally covered by the eyelids, could likewise have bearing on the question of exposure to sunlight.

It seems unlikely that the association between sunlight and "cancer eye" was the result of some peculiarity in the data, that is, diagnoses differing among herds, or the use of surgery to remove lesions in some herds and not in others, or the feeding of high levels of supplements in some and not in others, or pigment differing among herds. Herds using surgery were randomized among levels with regard to the three criteria of sunlight. The other possibilities were not measurable, but it is conceivable that their effects were cancelled in the pooling process. The fact that an association between sunlight and "cancer eye" was found with different and more or less independent criteria provides strong though by no means definitive assurance that these effects were not involved. Further analyses will be conducted with the more numerous and refined data from direct observation of animals in 45 herds in 23 states to ascertain the validity of the present results.

Summary and Conclusions

Disposal records from nine herds and pertaining to 4,960 animals whose ages ranged from 2½ to 18 years were used to investigate the effect of sunlight on "cancer eye". The age-adjusted incidence increased significantly with: (1) increase in average annual hours of sunshine; (2) decrease in average latitude; and (3) increase in average altitude. These criteria were thought to reflect differences in the ultraviolet component of sunlight. Other evidence of an association between sunlight and cancer in the bovine, man and laboratory animals was also mentioned.

Literature Cited

Anderson, D. E. 1960a. Studies on bovine ocular squamous carcinoma ("Cancer Eye") V. Genetic aspects. J. Heredity 51:51.

Anderson, D. E. 1960b. Studies on bovine ocular squamous carcinoma ("Cancer Eye") X. Nutritional effects. J. Animal Sci. 19:790.

Anderson, D. E., J. L. Lush and D. Chambers. 1957. Studies on bovine ocular squamous carcinoma ("Cancer Eye") II. Relationship between eyelid pigmentation and occurrence of cancer eye lesions. J. Animal Sci. 16:739.

Black, W. L. 1934. Survey on the cause of cancer eye in cattle. Extension Animal Husbandman. 33:9.

Blum, H. F. 1959. Carcinogenesis by Ultraviolet Light. pp. 285–305. Princeton University Press. Princeton, N. J.

Bonsma, J. C. 1949. Breeding cattle for increased adaptability to tropical and subtropical environments. J. Agr. Sci. 39:204.

Dorn, H. F. 1944. Illness from cancer in the United States. Pub. Health Repts. 59:33–48, 65–77, 97–115.

French, G. T. 1959. A clinical and genetic study of eye cancer in Hereford cattle. Australian Vet. J. 35:474.

Guilbert, H. R., A. Wahid, K. A. Wagnon and P. W. Gregory. 1948. Observations on pigmentation of eyelids of Hereford cattle in relation to occurrence of ocular epitheliomas. J. Animal Sci. 7:426.

Knox, J. H. 1949. Occurrence of cancer eye in range cattle. Ranch Day, Oct. 10. N. Mex. Exp. Sta.

Pearl, R. 1940. Medical Biometry and Statistics. (3rd ed.), pp. 274–281. W. B. Saunders Co., Philadelphia.

Rice, E. B. 1949. A survey of the dairy industry in Fiji, with particular reference to costs of production of butterfat. Council Paper No. 23. Legislative Council of Fiji.

Russell, W. O., E. S. Wynne and G. S. Loquvam. 1956. Studies on bovine ocular squamous carcinoma ("Cancer Eye") I. Pathological anatomy and historical review. Cancer 9:1.

Sykes, J. A., L. Dmochowski, E. S. Wynne and W. O. Russell. 1961. Bovine ocular squamous carcinoma IV. Tissue culture studies of bovine ocular squamous cell carcinoma and its benign precursor lesions. J. Nat. Cancer Inst. 26:445.

EFFECT OF PHYSICAL FORM OF THE RATION ON STEER PERFORMANCE AND CERTAIN RUMEN PHENOMENA[1]

A. E. CULLISON

University of Georgia, Athens

NUMEROUS tests have been conducted by various workers (Beardsley *et al.*, 1959; Cmarik *et al.*, 1957; Cullison *et al.*, 1960; Klosterman *et al.*, 1960; McCroskey *et al.*, 1960; Webb *et al.*, 1957) over the past few years to study the feasibility of using pelleted rations for feeding beef cattle. Since grinding is ordinarily prerequisite to pelleting, the role which the former process plays in the nutritive value of pelleted feeds has also come under study.

Pelleting high-roughage rations has, in general, resulted in a marked improvement in animal performance. Pelleting high-grain rations, on the other hand, has, in most instances, tended to lower animal performance.

Improved performance from the pelleting of high-roughage rations has usually been associated with an increased rate of feed consumption. This phenomenon might be explained, at least in part, as the result of a more rapid passage of pelleted roughages through the digestive tract (Blaxter *et al.*, 1956).

On the other hand, lowered animal performance from the pelleting of high-grain rations has usually been associated with a decreased rate of feed consumption. While a lower rate of feed consumption might explain the lowered performance resulting from the pelleting of high-grain rations, in so far as the writer is aware, no explanation of why pelleting should reduce the rate of consumption of such rations has ever been offered.

It is the purpose of this paper to report the results of three separate experiments dealing with the use of ground and pelleted rations for feeding beef animals and to present certain observations and data that may throw new light on some of the phenomena involved in this connection.

Experimental

Trial 1. In the first of three feeding trials herein reported, field cured Coastal Bermudagrass *(Cynodon dactylon)* hay of about average quality was compared in the long, ground and pelleted forms as a wintering feed for weanling beef calves. Three groups of 12 calves each were fed all they would consume of the Coastal Bermuda-grass hay in the three different forms, respectively, with 2 lb. cottonseed meal per head daily over a period of 133 days. Data on feed consumption and live-weight gains were obtained.

TABLE 1. RATION USED IN TRIALS 2 AND 3

Ingredient	Percent
Coastal Bermuda-grass hay	30.00
Ground shelled corn	50.00
Cottonseed meal (41% protein)	10.00
Blackstrap molasses	9.00
Defluorinated phosphate	.33
Ground limestone	.33
Salt	.34
Total	100.00

Trial 2. In a second test, the effect of grinding and pelleting a complete ration of grain and hay in fattening steer calves were studied. Three groups of 12 steer calves each were fed for a period of 196 days on a ration the make-up of which is given in table 1.

The average chemical composition of the ration based on the analyses of samples taken at intervals during the study is shown in table 2.

Group I was full-fed by hand twice daily. The hay was fed in the long form separate from the rest of the ration. The various feeds were always provided, however, in the same proportions.

TABLE 2. AVERAGE CHEMICAL COMPOSITION OF RATION USED IN TRIALS 2 AND 3

Component	Percent
Moisture	9.98
Crude protein	12.22
Crude fiber	10.85
Crude fat	3.12
Nitrogen-free extract	59.99
Ash	3.84
Total	100.00

[1] Journal paper No. 156 of the College Experiment Station of the University of Georgia College of Agriculture Experiment Stations.

Group II was self-fed on the same combination of feeds, all finely ground and mixed together. Group III was self-fed on a similar mixture except in the pelleted form. Slaughter information, as well as data on feed consumption and live weight gains, was obtained in this test.

Trial 3. In Trial 3, five groups of ten steer calves each were fed over a period of 210 days. Groups I, II and III were fed the same as were Groups I, II and III of Trial 2. Groups IV and V were fed the same as were Groups II and III, respectively, except that each of the former groups were provided with oat straw on an *ad libitum* basis in addition to the basic ration.

The purpose of the straw was to determine what influence, if any, the presence of some long roughage might have on the utilization of the ground and pelleted rations. Oat straw was used rather than hay since it was felt that the straw would not be eaten in sufficient quantities to interfere greatly with the animals' consumption of the basic ration, as might a more palatable roughage. Also, it was not believed likely that the straw would contain any nutrients which might unknowingly be critical with the ration being fed. Still, it should serve to satisfy any craving or need the animals might have for long roughage in the diet.

As in Trial 2, slaughter information, as well as figures on feed consumption and live weight gains, was obtained. Also, observations were made on the condition of the rumen wall and data were obtained on the pH of the rumen contents.

Three different procedures were followed in obtaining the latter information. One series of pH determinations was made on samples obtained from the rumen by means of a vacuum pump attached to a stomach tube with an intervening collection jar. A second set of determinations was made on samples of rumen contents obtained from the animals on the various treatments at the time of slaughter. A third series of rumen pH readings was made by the use of a special electrode arrangement which could be inserted down the esophagus into the rumen.

In conjunction with Trial 3, a second set of calves was placed on Treatments I, III, and V to serve for the purpose of interval slaughter and rumen examination. Representative animals from each of the above treatments were sacrificed at 91, 210 and 293 days. A few animals were continued on the all pellet ration for over a year.

In all three experiments, animals were assigned to treatment by stratified randomization. Significance of differences was determined by the analysis of variance and the application of Duncan's (1955) and Kramer's (1956) Multiple Range Tests.

Results and Discussion

Trial 1. The results of Trial 1 are summarized in table 3. The calves on the ground hay consumed 30.0% more hay or 24.8% more total feed and made 52.0% faster gains than did those receiving hay in the long form. The calves on the pelleted hay consumed 39.4% more hay or 32.0% more total feed and made 99.0% faster gains than did the control group.

The calves on both the long and ground hay readily cleaned up their daily allowance of cottonseed meal when it was provided in a trough separate from the hay. The calves re-

TABLE 3. GRINDING AND PELLETING COASTAL BERMUDA-GRASS HAY FOR WINTERING BEEF CALVES

Group	I	II	III	
Treatment	Long hay, CSM and minerals	Ground hay, CSM and minerals	Pelleted hay, CSM and minerals	Tests of significance[b]
No. of calves	12	12	12	
Days on test	133	133	133	
Av. daily gain, lb.	.73	1.11	1.45	(I) (II) (III)
Av. daily ration:				
Coastal Bermuda hay, lb.	10.30	13.38	14.36	
Cottonseed meal, lb.	2.00	2.00	1.91	
Minerals,[a] lb.	.10	.10	.10	
Total	12.40	15.48	16.37	
Feed per lb. gain, lb.	17.0	13.9	11.3	

[a] Consisted of 2 parts defluorinated phosphate and 1 part salt.
[b] The means for any two treatment groups not enclosed by the same parentheses are significantly different ($P<.05$).

TABLE 4. GRINDING AND PELLETING A COMPLETE RATION FOR FATTENING STEER CALVES

Group	I	II	III	
Treatment	Control	Ground	Pelleted	Tests of significance[b]
No. of animals	12	12	12	
Days on test	196	196	196	
Av. initial wt., lb.	526.7	528.2	525.2	
Av. daily gain, lb.	2.41	2.53	2.17	(I, II) (I, III)
Av. daily feed consump., lb.	19.7	19.7	16.8	
Feed per lb. of gain, lb.	8.18	7.76	7.75	
Av. slaughter grade[a]	14.9	15.8	15.3	(I, II, III)
Av. carcass grade[a]	14.8	14.8	13.3	(I, II) (III)
Av. dressing %	59.74	60.76	59.63	(I, II, III)

[a] 16=Low Choice; 15=High Good; 14=Good; 13=Low Good.
[b] The means for any two treatment groups not enclosed by the same parentheses are significantly different ($P<.05$).

ceiving the Coastal Bermuda-grass hay pellets, however, preferred the pellets to the cottonseed meal and would eat the latter only when forced to do so by the inclusion of the cottonseed meal in the feeder with the pellets. Something happened during the pelleting process that changed the ground hay material from a product less palatable to a product more palatable than cottonseed meal in so far as a beef animal is concerned. This improved palatability might be at least partly responsible for the greater consumption by the calves of the pelleted product.

Trial 2. The results of feeding trial number 2 in this study are reported in table 4. The steers receiving their ration in the pelleted form had a lower level of feed consumption and rate of gain than did those on the control or the ground ration. This was in contrast to the results obtained from the use of the all-hay pellets in the previous trial.

While feed per pound of gain, slaughter and carcass grades and dressing percent are included in table 4, nothing of particular importance is to be found among these data except, possibly, for the fact that Group III graded two-thirds of a grade lower in the carcass than it did on foot. Contributing to the latter was the fact that there were some carcasses with off-color lean among this group.

Trial 3. The results of Trial 3 are reported in table 5. As in Trial 2, those animals receiving the pelleted ration gave a poorer perform-

TABLE 5. GROUND AND PELLETED RATIONS, WITH AND WITHOUT OAT STRAW, FOR FATTENING STEER CALVES

Group	I	II	III	IV	V	
Treatment	Control	Ground	Pelleted	Ground + Straw	Pelleted + Straw	Tests of significance[b]
No. of animals	10	10	10	10	10	
Days on test	210	210	210	210	210	
Av. initial wt., lb.	390.0	391.3	390.6	388.9	389.9	
Av. daily gain, lb.	2.10	2.03	1.64	2.27	2.25	(III) (I, II) (I, IV, V)
Av. daily feed consump.:						
Basic ration, lb.	17.12	15.44	13.53	17.36	17.06	
Oat straw, lb.	.....	.....	.....	1.35	1.49	
Total	17.12	15.44	13.53	18.71	18.55	
Feed per lb. gain:						
Basic ration, lb.	8.16	7.62	8.26	7.65	7.59	
Oat straw, lb.	....	....	....	.60	.66	
Total	8.16	7.62	8.26	8.25	8.25	
Av. slaughter grade[a]	15.0	15.0	13.6	15.3	16.0	(III) (I, II, IV, V)
Av. carcass grade[a]	14.7	14.9	13.0	15.1	15.5	(III) (I, II, IV, V)
Av. dressing %	59.48	59.29	56.99	59.25	59.30	(III) (I, II, IV, V)

[a] 16=Low Choice; 15=High Good; 14=Good; 13=Low Good.
[b] The means for any two treatment groups not enclosed by the same parentheses are significantly different ($P<.05$).

ance than did those on either the control or ground ration. Also, those animals in Groups IV and V, receiving oat straw on an *ad libitum* basis, in addition to the basic ration, consumed only 1.35 and 1.49 lb. of straw per head daily, respectively. However, these amounts of straw were sufficient to stimulate these animals to consume considerably more of the basic ration and, accordingly, to gain significantly faster than did those in Groups II and III, respectively, which were comparable except for receiving no straw. Apparently, the low rate of consumption of the basic ration in the pelleted form was not a matter of palatability or acceptability of the pellets but rather one of rate of utilization on the part of the animal.

Observations on Rumen Wall Condition. In both Trials 2 and 3, varying degrees of an abnormal rumen wall condition such as was reported by Beardsley *et al.* (1959) were noted at the time of slaughter among those animals on both the ground and pelleted rations following feeding periods of 196 and 210 days, respectively. The condition was characterized by the presence of excessively long, dark, unhealthy appearing papillae and the sloughing off of areas of keratinous tissue from the rumen wall.

In contrast, those animals on the control ration of concentrates and long hay exhibited a uniformly normal rumen wall condition. Also, those animals which received straw with the basic ration in the ground or pelleted form in Trial 3 displayed rumen walls quite similar to those of the control animals except for having somewhat of a yellow color as compared to more of a grayish color for the controls. It was not determined how long it took the abnormal condition to develop, but it was clearly present in an animal sacrificed after being on pellets for 91 days. Furthermore, the condition continued to present itself with certain minor deviations in animals fed on pellets for a period of over one year.

Observations on Rumination and Cud Chewing. Day-long checks during the latter part of the feeding period revealed no normal rumination and cud chewing among those animals on either the ground or pelleted ration. In contrast, normal rumination and cud chewing occurred in the cattle in Groups I, IV and V receiving either long hay or straw.

Data on pH of Rumen Contents. On the slaughter of animals at the end of 91 days of feeding in the control, the pellets only and the pellets-plus-straw treatments, it was noted that the contents of the rumen of the steer which had received pellets only seemed to have a more acid odor than did the rumen contents of the other two animals. A pH determination on the contents of the respective rumens showed a lower pH for the steer receiving pellets only.

An effort was made to obtain, for additional pH determinations, samples of rumen contents from those steers in the regular feedlot test. As mentioned previously, a vacuum pump connected to a stomach tube with an intervening collection jar was used for this purpose. Samples were obtained from all of the animals in the control and pellet groups and from 4 and 3 animals, respectively, of the ground and the pellets-plus-straw groups. Samples were taken from the control group from 1 to 3 hours following feeding, at which time the pH of the rumen contents of this group should have been at its lowest (Dukes, 1955). Samples were obtained from the other groups, which were all self-fed, as convenient during the day but in all instances, animals were held off feed for at least one hour before samples were taken. The results of these determinations are shown in the top row of figures of table 6. The average pH reading for the pellet group was significantly below that of the control, and also considerably below that for the ground and the pellet-plus-straw groups although the number of observations in the latter two groups did not permit their being included in the statistical analysis.

In an effort to check the first series of pH observations, a second set of determinations was made on samples of rumen contents obtained from the animals on the various treatments at the time of slaughter. The results of this set of determinations are given in the middle row of figures of table 6. The same trend in pH exists among these data as was found in the first series of observations, although the differences did not prove to be statistically significant.

In view of the latter results, it was felt that additional data should be obtained before drawing conclusions. Fortunately, a large portion of those three groups of animals which had been set up on treatments I, III and V, respectively, for interval slaughter and rumen observation and study, was still available. A series of rumen pH readings was made on these animals by the use of a special electrode arrangement which could be inserted down the esophagus into the contents of the

TABLE 6. EFFECT OF PHYSICAL FORM OF THE RATION ON RUMEN pH

Group	I	II	III	IV	V	
Treatment	Control	Ground	Pelleted	Ground + Straw	Pelleted + Straw	Tests of significance[a]
On samples pumped from rumen of live animal	7.10	6.56	5.50	....	7.97	(I) (III)[b]
On samples obtained from rumen at slaughter	5.55	5.37	5.30	5.59	5.51	(I, II, III, IV, V)
By direct readings using special electrode in live animal	6.28	....	5.22	....	6.45	(I, V) (III)

[a] The means for any two treatment groups not enclosed by the same parentheses are significantly different ($P<.05$).
[b] Number of observations in II and V too limited for statistical analysis.

rumen. The results of these determinations are given in the bottom row of table 6. It will be noted that these data confirm, in a general way, those obtained in the first series of determinations and indicate a lower rumen pH for animals on the pelleted ration.

Such a condition could have been the result of a more active fermentation in the group on pellets only or perhaps a different type of fermentation in this group. It also could have been that the acids of fermentation tended to accumulate in the rumen of the animals on pellets. This might result from either a slower absorption of the acids from the rumen or a slower neutralization of these acids by the salivary secretion, or a combination of these factors.

In view of existing information, the latter possibility is indicated. It is estimated by Dukes (1955) that the ox will secrete something like 56,000 gm. of saliva in 24 hours. He states that one of the special functions of saliva in the rumen is the neutralization of organic acids produced by bacterial action and that the normal stimulus of salivation in ruminants is considered to be roughage in the diet. This latter point is supported by the work of Balch (1958).

Pelleted feeds, even though they contain a high percentage of hay, act as concentrates from the standpoint of their physical properties due to their increased density. When a ground but unpelleted mixture is immersed in water, it tends to separate into two fractions with the fraction that is lighter than water rising to the top and the other fraction sinking to the bottom. Most pelleted feeds, on the other hand, when immersed in water sink and remain at the bottom in their entirety even after disintegration of the pellet.

This difference in the physical properties of the two forms of the same feed mixture and in the effect which each form would have on salivary stimulation could be responsible for the higher rumen pH and superior performance of those steers receiving the ground ration as compared to those on the pellets. Also, the higher rumen pH and superior performance of those groups receiving straw as compared to those on comparable rations, but without straw, could be explained on the same basis. The higher rumen pH and superior performance of the control group as compared to the pellet group could be explained in the same way.

Summary

The results of three separate experiments dealing with the use of ground and pelleted rations for feeding beef cattle are reported. In the first experiment, Coastal Bermudagrass *(Cynodon dactylon)* hay was compared in the long, ground, and pelleted forms as a wintering feed for beef calves. The calves on the ground hay consumed 24.8% more feed and gained 52.0% faster and those on the pellets consumed 32.0% more feed and gained 99.0% faster than did those on the long hay. A definite preference was displayed by the calves for the pelleted hay.

In the other two experiments, a complete high-grain ration was compared in the conventional, ground, and pelleted forms for finishing steer calves. In both tests, those steers receiving their entire ration in the pelleted form consumed less total feed and gained slower than did those on either the conventional or ground ration. However, feeding approximately one and one-half pounds of oat straw per head daily caused calves receiving basic ration pellets in addition to consume 26.1% more pellets and to gain 37.2% faster than did those calves receiving pellets only.

No normal rumination and cud chewing were noted among animals receiving pellets only or the completely ground ration. An abnormal rumen wall condition resulted among the last two groups. The condition was corrected by the feeding of straw.

Significantly lower rumen pH levels were found among those steers receiving pellets only. An inadequate secretion of saliva is offered as an explanation of this phenomenon.

Literature Cited

Balch, C. C. 1958. Observations on the act of eating in cattle. Brit. J. Nutr. 12:330.

Beardsley, D. W., W. C. McCormick and B. L. Southwell. 1959. Steer performance on and rumen effects of different concentrate: roughage ratios in pelleted and unpelleted mixed fattening rations. J. Animal Sci. 18:1507. (Abstr.)

Blaxter, K. L., N. McC. Graham and F. W. Wainman. 1956. Some observations on the digestibility of food by sheep and on related problems. Brit. J. Nutr. 10:69.

Cmarik, G. F., R. J. Webb and H. A. Cate. 1957. The response of fattening yearling steers self-fed complete pelleted rations of varying ratios of concentrates to roughages. J. Animal Sci. 16:1085. (Abstr.)

Cullison, A. E., R. M. Walker and B. M. Campbell. 1960. Effect of physical form of the ration on steer performance and certain rumen phenomena. J. Animal Sci. 19:1256. (Abstr.)

Dukes, H. H. 1955. The Physiology of Domestic Animals. (7th ed.) Comstock Publishing Associates, Ithaca, New York.

Duncan, David B. 1955. Multiple range and multiple F tests. Biometrics 11:1.

Klosterman, E. W., G. E. Ricketts and R. R. Johnson. 1960. Nutritive value of mixed hay fed as the sole ration in the long, ground and pelleted forms. J. Animal Sci. 19:1271. (Abstr.)

Kramer, C. Y. 1956. Extension of multiple range tests to group means of unequal numbers of replications. Biometrics 12:307.

McCroskey, J. E., L. S. Pope, D. F. Stephens and George Waller. 1960. Effect of pelleting *per se* on the utilization of milo and high roughage rations by steer calves. J. Animal Sci. 19:1275. (Abstr.)

Webb, R. J., G. F. Cmarik and H. A. Cate. 1957. Comparison of feeding three forages as baled hay, chopped hay, hay pellets and silage to steer calves. J. Animal Sci. 16:1057. (Abstr.)

LIGNIN EXCRETION BY CATTLE FED A MIXED RATION[1]

C. J. Elam and R. E. Davis[2]

U. S. Department of Agriculture[3]

LIGNIN has been used widely as an internal indicator in digestion studies, especially in forage evaluation.

The lignin-ratio technique does not require the total collection of feces, but if partial collection is used it is necessary that the feces sample be representative of the total in regard to its concentration of lignin and any nutrients determined.

Kane *et al.* (1952) reported a statistically significant difference between the a.m. and p.m. concentrations of lignin in the feces of dairy cows fed long hay, silage, and grain. However, additional information is needed in regard to the excretion of lignin by cattle fed mixed rations.

The present experiments were conducted to determine the nature of the excretion pattern of lignin by cattle fed a complete pelleted ration.

Experimental Procedure

Excretion Pattern. The ration consisted of 49.0% corn and cob meal, 14.7% cottonseed meal, 24.5% grass hay, 9.8% molasses, 1.0% salt, and 1.0% bonemeal. Chromic oxide was added at a level of 10 lb. per ton and vitamin A was supplied according to NRC recommendations.

Six Hereford heifers were used in each of the two phases of this trial. During the first phase, three heifers were group-fed the complete pelleted ration *ad libitum* and three were full-fed once daily. In the second phase, three heifers were individually-fed a limited quantity of feed once daily and three were full-fed twice a day. After at least 9 days, feces samples were collected from each heifer at 3-hour intervals for 48 hours.

Lignin analyses were conducted on feces samples collected during the first 24 hours by a modification[4] of the method of Ellis *et al.* (1946). All samples were analyzed in duplicate allowing a difference of 3% of the amount present between duplicates.

Prior to lignin analysis, dried feces samples were ground in a Wiley mill using a 40-mesh screen.

Digestibility Trial. Four Hereford steers weighing approximately 750 lb. were used in a conventional 10-day total collection digestion trial. The complete pelleted ration used in Trial I was fed twice a day at 8:00 a.m. and 3:30 p.m. Following a 2-week feeding period the steers were placed in digestion stalls for 21 days. After a 10-day preliminary period, total feces were collected for 10 days and aliquot samples were dried daily in a forced draft oven at 70° C. for about 36 hours. Dried samples were processed as described above.

On the 21st day, feces samples were collected at 3-hour intervals for 24 hours. Equal weights of dried feces from each of the four steers were combined for each time. The feed sample and fecal samples were analyzed for lignin by the method of Ellis *et al.* (1946) and for chromic oxide by the method of Christian and Coup (1954), with slight modifications.

Results

Excretion Pattern. Figure 1 shows the fecal lignin concentration as affected by time and schedule of feeding. The concentration of lignin in the feces is shown as a percentage of the daily mean concentration. The chromic oxide excretion pattern in the samples, previously reported by Elam *et al.* (1959), is also shown in figure 1 in order to allow a comparison of the two indicators.

The concentration of lignin in the feces was relatively uniform and was not influenced significantly by time. In addition, no interaction existed between treatments and time, indicating that the fecal lignin values were not altered by the feeding schedules. These results with lignin are contrasted to the chromic oxide excretion pattern (Elam *et al.*,

[1] Presented in part at the 52nd Annual Meeting of the American Society of Animal Production, Chicago, Illinois, November 26, 1960.

[2] The authors express their appreciation to C. Jackson, P. W. Kerns, J. R. Randall, and E. Riddle for technical assistance.

[3] Beef Cattle Research Branch, AHRD, ARS, ARC, Beltsville, Md.

[4] Autoclaving for 30 minutes replaced the refluxing called for in the original method.

1959) in which there were effects from both time and feeding schedules (figure 1).

It is clear that the lignin content of the feces was less variable than the chromic oxide content. The extreme range in fecal lignin among the 96 observations was from 87.8 to 109.2% of the daily mean with a standard deviation of 4.0%. The chromic oxide content ranged from 74.0 to 135.1% of the daily mean with a standard deviation of 10.1%.

Digestibility. An average of 12.9% of the lignin fed in the ration was digested by the four steers. Individual coefficients of apparent lignin digestion ranged from 11.1 to 14.6 among the steers.

Lignin concentration in the feces varied little during the day; ranging from 97.5 to 103.0% of the daily mean with a standard deviation of 1.9%. These figures represent an average of four steers.

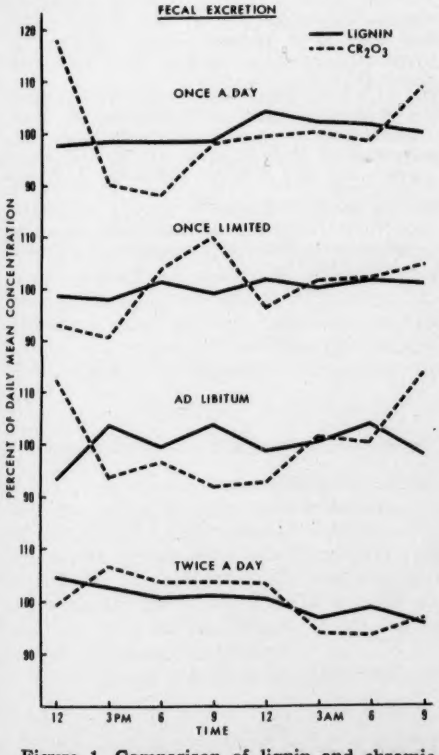


Figure 1. Comparison of lignin and chromic oxide (Elam et al., 1959) excretion as affected by feeding schedule and time of sampling. Each point represents an average of three observations.

Chromic oxide concentration in the feces ranged from 93.8 to 106.0% of the daily mean concentration with a standard deviation of 4.3%. The results of the two trials showed less variation with time of day in the concentration of lignin in the feces than chromic oxide.

Chromic oxide recovery averaged 97.3% in this trial.

Discussion

The lignin results of this experiment appear to conflict with those of Kane *et al.* (1952). They reported that a diurnal pattern existed for both lignin and chromic oxide in the feces of dairy cows. The chromic oxide concentration was more variable than lignin, but there did appear to be considerable variation in fecal lignin concentration with time of day. However, when their data are expressed as a percentage of the daily mean the lignin excretion was relatively uniform. Although there was a statistically significant difference between a.m. and p.m. concentrations of fecal lignin, the majority of individual observations were within 3% of the daily mean. This small variation could have caused only a relatively small error in digestion coefficients calculated by the lignin ratio technique.

We conclude from the results of the present experiment and from those of Kane *et al.* (1952) that the time of "grab" sampling feces is of little importance when the lignin ratio technique is used to determine digestibility.

The low recovery of lignin in the present experiment would, however, seriously limit its use as an indicator. Using essentially the same chemical technique for lignin analysis, some workers (Davis *et al.*, 1947; Ely *et al.*, 1953; Kane *et al.*, 1953; Sullivan, 1955) have reported a similar degree of apparent lignin digestion while others (Ellis *et al.*, 1946; Swift *et al.*, 1947; Forbes and Garrigus, 1948; Kane *et al.*, 1950) have recovered all the lignin fed. Forbes and Garrigus (1950) reported negative lignin digestion averaging 5% for steers and 14% for wethers.

The empirical nature of the techniques used for lignin analysis raises the question of whether the lignin recovered in the feces is the same structurally as that fed? Several workers (Csonka *et al.*, 1929; Ely *et al.*, 1953; Salo, 1958) have reported that the methoxyl content of lignin changed while passing through the digestive tracts of cows.

Lignin appears to be of questionable value

as an indicator when precise coefficients of digestion are desired, but may be of value for comparative purposes where the lignin content of rations are the same.

Summary

Lignin analyses of feces samples collected at three-hour intervals from beef heifers fed a mixed ration indicated only slight variations in lignin concentration during a 24-hour period. Four different feeding schedules showed no evidence of effect on fecal lignin excretion pattern.

Results of a digestion experiment using four beef steers indicated that an average of 87.1% of the lignin fed was recovered in the feces.

The lignin data are compared to the results of chromic oxide analyses of the same feces samples and the significance of the results in regard to the ratio technique of determining digestibility is discussed.

Literature Cited

Christian, K. R. and M. R. Coup. 1954. Measurement of feed intake by grazing cattle and sheep. VI. The determination of chromium oxide in feces. New Zealand J. Sci. Tech. A. 36:328.

Csonka, F. A., M. Phillips and D. B. Jones. 1929. Studies on lignin metabolism. J. Biol. Chem. 85:65.

Davis, R. E., C. O. Miller and I. L. Lindahl. 1947. Apparent digestibility by sheep of lignin in pea and lima-bean vines. J. Agr. Res. 74:285.

Elam, C. J., P. A. Putnam and R. E. Davis. 1959. Fecal excretion pattern of chromic oxide administered to Hereford heifers in a completely pelleted ration. J. Animal Sci. 18:718.

Ellis, G. H., G. Matrone and L. A. Maynard. 1946. A 72 percent H_2SO_4 method for the determination of lignin and its use in animal nutrition studies. J. Animal Sci. 5:285.

Ely, R. E., E. A. Kane, W. C. Jacobson and L. A. Moore. 1953. Studies on the composition of lignin isolated from orchard grass hay cut at four stages of maturity and from the corresponding feces. J. Dairy Sci. 36:346.

Forbes, R. M. and W. P. Garrigus. 1948. Application of a lignin ratio technique to the determination of the nutrient intake of grazing animals. J. Animal Sci. 7:373.

Forbes, R. M. and W. P. Garrigus. 1950. Some effects of forage composition on its nutritive value when cut and fed green to steers and wethers, as determined conventionally and by the lignin ratio. J. Animal Sci. 9:531.

Kane, E. A., R. E. Ely, W. C. Jacobson and L. A. Moore. 1953. A comparison of various digestion trial techniques with dairy cattle. J. Dairy Sci. 36:325.

Kane, E. A., W. C. Jacobson and L. A. Moore. 1950. A comparison of techniques used in digestibility studies with dairy cattle. J. Nutr. 41:583.

Kane, E. A., W. C. Jacobson and L. A. Moore. 1952. Diurnal variation in the excretion of chromium oxide and lignin. J. Nutr. 47:263.

Salo, M. L. 1958. Lignin Studies. III. Lignin as tracer in digestibility investigations. Maataloust. Aikakausk. 30:97.

Sullivan, J. T. 1955. Cellulose and lignin in forage grasses and their digestion coefficients. J. Animal Sci. 14:710.

Swift, R. W., E. J. Thacker, A. Black, J. W. Bratzler and W. H. James. 1947. Digestibility of rations for ruminants as affected by proportions of nutrients. J. Animal Sci. 6:432.

EFFECT OF PRESLAUGHTER CHANGE TO A COLD ENVIRONMENT ON CHARACTERISTICS OF PORK MUSCLE [1, 2]

R. N. Sayre, E. J. Briskey, W. G. Hoekstra and R. W. Bray

University of Wisconsin,[3] Madison

THE quantity of glycogen in pork muscle at the time of slaughter holds a significant relationship to the ultimate pH and water-binding capacity of the chilled muscle tissue (Callow, 1937; Briskey *et al.*, 1959a; Wismer-Pedersen, 1959a). Briskey *et al.* (1959b) reported that exhaustive exercise immediately prior to slaughter significantly decreased the initial glycogen content of the muscle with a resultant higher pH of the chilled muscle and an apparent trend toward increased water-binding. Hall *et al.* (1944) found that severe climatic exposure of beef calves accustomed to mild conditions resulted in a high incidence of dark cutting beef. Briskey *et al.* (1960a) have reported variations in the ultimate pH of pork muscle as a result of a major environmental change, while Wismer-Pedersen (1959b), Ludvigsen (1954), and Judge *et al.* (1959) have noted a higher incidence of soft, watery muscle during the warm summer months.

The experiments reported in this paper were designed to study the influence of a severe change in an animal's immediate environment upon glycogen content at the time of death, post-mortem lactic acid production, and water-binding capacity of the muscle tissue.

Experimental Procedure and Results

Two experiments were conducted during the late spring with an ambient temperature of 24° to 26° C. All animals were fasted 12 hr. before experimental procedures were initiated. All animals, except the controls, were subsequently placed in 16 in. of ice cold water (0.5° C.) in an attempt to simulate a severe environmental change.

Physical and Chemical Measurements. As the animals were bled samples of the *gluteus medius* muscle (Briskey *et al.*, 1960b) were removed from the right ham and measurements were made within 10 min. The pH values were determined with a Beckman Model "G" pH meter (Briskey *et al.*, 1959a). The water-binding capacity of the muscle was measured by the technique of Grau and Hamm (1953) as modified by Briskey *et al.* (1960b). Area measurements were converted to percent expressible juice by a modification of the formula of Wierbicki and Deatherage (1958). Samples were also frozen in dry ice for later determination of glycogen (Hansen *et al.*, 1952), total moisture, and ether extract (A.O.A.C., 1955). Liver samples were simultaneously secured and frozen for similar analyses.

Following a 24-hr. post-mortem chilling period the hams were removed from the left sides of the carcasses as outlined by the Pork Carcass Evaluation Committee (1952). Samples from the exposed *gluteus medius* muscles were taken for determination of water-binding capacity and pH value. Additional samples were frozen and subsequently analyzed for lactic acid concentration by the method of Barker and Summerson (1941). The freshly cut ham butts were subjectively scored, independently by three individuals, for color intensity and "watery appearance". Four color classifications were used with 1, very pale; 2, light color; 3, normal grayish pink; and 4, dark. The three "wateriness" scores were 1, wet; 2, normal; and 3, dry.

Statistical Analysis. Treatment means were tested for statistical differences by analysis of variance and Duncan's multiple range procedure as outlined by Steel and Torrie (1960). Simple correlations were determined for all observations, disregarding treatments, and therefore represent total correlations for all animals in the experiment.

Experiment I. Eighteen market-weight barrows self-fed a 13% protein basal ration were used in the first experiment. The animals were blocked by weight groups and ran-

[1] Published with the approval of the Director of the Wisconsin Agricultural Experiment Station.

[2] This investigation was supported in part by a research grant (RG-5725) from the Department of Health, Education and Welfare, Public Health Service, National Institutes of Health; Wisconsin Alumni Research Foundation and by partial support from Armour and Company.

[3] Departments of Animal Husbandry and Biochemistry, cooperating.

domly assigned to three lots of six pigs each. Lot I served as the control in this experiment. Pigs of Lot II were placed in cold water for 30 min. and slaughtered 10 min. after termination of treatment. Pigs of Lot III received a similar cold water treatment but were slaughtered 3 hr. after termination of treatment.

Treatment means for the various characteristics studied are presented in table 1. The severe environmental change produced by the cold water bath was effective in significantly

TABLE 1. EFFECT OF CHANGE TO A COLD ENVIRONMENT ON CERTAIN PROPERTIES OF THE *GLUTEUS MEDIUS* MUSCLE OF BARROWS

(EXPERIMENT I—BASAL RATION)

Chemical and physical characteristics	Control	Immersion of pigs[a] in 0.5° C. H_2O for 30 min.	
	Lot I 12 hr. fast	Lot II Held 10 min. pre-slaughter	Lot III Held 3 hr. pre-slaughter
Muscle glycogen [b]	25.41	18.24	17.88
pH (initial)	6.67	6.73	6.76
pH (24 hr.)	5.48	5.69	5.68
Lactic acid % [c]	3.92*	3.40	3.42
Color score	2.67*	3.75	3.50
Wateriness score	1.3	2.3	2.3
Expressible water % (initial)[d]	59.20	60.71	67.93*
Expressible water % (24 hr.)[d]	76.25	68.19	73.57
△ Expressible water %[d]	17.05	7.47	5.64
Moisture %[e]	74.82	74.84	74.63
Protein %[f]	22.51	22.12	22.23
Lipid %[c]	10.57	11.80	11.87
Liver glycogen[g]	22.34	14.25	8.44

[a] All pigs fasted 12 hr. prior to immersion in H_2O.
[b] Mg. glycogen per gm. of fat-free, dry tissue (at time of slaughter).
[c] Dry weight basis (24 hr. samples).
[d] Percent of total moisture.
[e] Wet weight basis.
[f] Found by difference after drying and lipid extraction (wet weight basis).
[g] Samples taken at the same time as initial *gluteus medius* muscle samples. Glycogen values expressed on same basis as indicated for muscle glycogen.
* Significantly different at the 5% level of probability from the underlined observation(s).

($P<0.05$) decreasing the lactic acid concentration in the chilled muscle. Consequently, the color intensity of the ham was significantly ($P<0.05$) darker in Lot II (held 10 min.) than in Lot I (control). Lot III (held 3 hr.), although not significantly darker than Lot I, tended to be similar in color intensity to Lot II. Water-binding capacity of the fresh muscle was significantly lower in Lot III than in the other two lots. This difference, however, was not found to be present in the chilled muscle.

The other treatment means failed to show significant differences at the 5% level of probability due, in part, to the large variation among animals which received similar treatment. Trends, however, appear to be present in the treated lots. Glycogen concentrations in the fresh muscle and liver tended to be decreased in Lot II and Lot III which partially explains the lower ultimate lactic acid content. As a result both fresh and chilled pH values appeared to be slightly higher in the treated lots. Water-binding capacity and wateriness score in the chilled muscle tended to increase in the treated lots. The change in water-binding capacity during the 24-hr. chilling period appeared to be greater in Lot I. Total moisture, protein, and lipid content of the muscle did not vary greatly between lots.

Simple correlations presented in table 2 show significant relationships among glycogen content of the fresh muscle, pH of the chilled muscle, lactic acid concentration in the chilled muscle, color score, wateriness score, water-binding capacity of the chilled muscle, and change in water-binding capacity of the muscle from the fresh to the chilled state. The only exceptions to the above relationships are that water-binding capacity and change in water-binding capacity failed to be significantly correlated with chilled pH; however, the figures approach significance. Neither water-binding capacity nor pH of the fresh muscle were significantly related to the other characteristics measured.

Experiment II. Twenty-five market-weight gilts were used in the second experiment. A 50% sucrose ration (Briskey *et al.*, 1959c) was self-fed for a 14-day period prior to slaughter with the hope of increasing muscle glycogen concentrations, and therefore, accentuating treatment effects. The animals were assigned to five lots of five animals each as described for the first experiment. The cold water treatment was extended to 40 min. Since all animals were fasted 12 hr. prior to treatment, Lot I was fasted 24 hr. prior to slaughter to act as a control for Lot III which was slaughtered 12 hr. after treatment. Lots II, IV, and V received treatments similar to Lots I, II, and III in the first experiment with the exception that Lot IV was slaughtered 20 min. after termination of stress rather than after a 10-min. interval.

Treatment means for the various characteristics measured are presented in table 3. Cold water exposure for 40 min. at the middle of a 24-hr. fasting period (Lot III) was effective in significantly ($P<0.05$) decreasing the glycogen concentration of the fresh

TABLE 2. CORRELATIONS BETWEEN CERTAIN CHEMICAL AND PHYSICAL CHARACTERISTICS OF THE *GLUTEUS MEDIUS* MUSCLE

(EXPERIMENT I—BASAL RATION)

Chemical and physical characteristics	Muscle glycogen (fresh)	pH (fresh)	pH (chilled)	Lactic acid (chilled)	Color score	Wateriness score	% Expressible water (fresh)	% Expressible water (chilled)
pH (fresh)	−.211	.....	.....	.....	.....	.....	.....	.....
pH (chilled)	−.646**	0.295	.....	.....	.....	.....	.....	.....
Lactic acid (chilled)	0.598**	−.420	−.794**	.....	.....	.....	.....	.....
Color score	−.609**	0.317	0.677**	−.798**	.....	.....	.....	.....
Wateriness score	−.569*	0.343	0.650**	−.761**	0.911**	.....	.....	.....
Expressible water % (fresh)	−.333	−.129	.....	.....	.....	0.213	.....	.....
Expressible water % (chilled)	0.519*	−.117	−.393	0.485*	−.766**	−.636**	0.034	.....
ΔExpressible water %	0.588*	−.059	−.460	0.486*	−.569*	−.545*	−.830**	0.535*

* $P<.05$, $r>.468$.
** $P<.01$, $r>.590$.

gluteus medius muscle below Lot II which was fasted for only 12 hr. without additional stress. The ham butts were significantly ($P<0.05$) darkened in color in Lot III (held 12 hr.) and Lot IV (held 20 min.) compared to Lot II (control). While other treatment means were not significantly different at the 5% level of probability, they follow the same general trends that appeared in Experiment I. Lactic acid concentrations tended to be lower in treated lots with corresponding higher pH values and wateriness scores. The largest change in water-binding capacity during the chilling period occurred in Lot II. The greater change was apparently the result of an increased initial water-binding capacity since in chilled muscle it was essentially the same for all lots. Liver glycogen reserves were extremely variable among animals within the same lot, especially in Lots II, IV, and V where the mean glycogen concentrations were high. The 24-hour fasting period in Lots I

TABLE 3. EFFECT OF CHANGE TO A COLD ENVIRONMENT ON CERTAIN PROPERTIES OF THE *GLUTEUS MEDIUS* MUSCLE OF GILTS

(EXPERIMENT II—HIGH SUCROSE RATION)

Chemical and physical characteristics	Controls		Immersion of pigs[a] in 0.5° C. H_2O for 40 min.		
	Lot I 24 hr. fast	Lot II 12 hr. fast	Lot III Held 12 hr. pre-slaughter	Lot IV Held 20 min. pre-slaughter	Lot V Held 3 hr. pre-slaughter
Muscle glycogen[b]	25.36	32.68	16.88*	24.23	25.33
pH (initial)	6.47	6.55	6.48	6.66	6.60
pH (24 hr.)	5.55	5.45	5.86	5.59	5.62
Lactic acid %[c]	4.06	4.28	3.54	3.96	4.18
Color score	2.94	2.36*	3.52	3.68	3.16
Wateriness score	2.1	1.6	2.4	2.8	2.1
Expressible water % (initial)[d]	51.11	46.72	49.40	50.79	49.31
Expressible water % (24 hr.)[d]	61.10	60.75	60.33	57.95	61.78
ΔExpressible water %[e]	9.99	14.03	10.93	7.16	12.48
Moisture %[e]	74.61	75.52	74.85	75.08	75.08
Protein %[f]	23.08	22.65	22.96	22.61	22.82
Lipid %[e]	8.96	7.46	9.04	9.49	8.42
Liver glycogen[g]	31.11	97.88	16.67	161.62	176.86

[a] All pigs fasted 12 hr. prior to immersion in H_2O.
[b] Mg. glycogen per gm. of fat-free, dry tissue (at time of slaughter).
[c] Dry weight basis (24 hr. samples).
[d] Percent of total moisture.
[e] Wet weight basis.
[f] Found by difference after drying and lipid extraction (wet weight basis).
[g] Samples taken at the same time as initial *gluteus medius* muscle samples. Glycogen values expressed on same basis as indicated for muscle glycogen.
* Significantly different at the 5% level of probability from the underlined observation(s).

and III tended to lower the glycogen level. Conversely, liver glycogen appeared to build up at 20 min. and 3 hr. following cold water treatment; however, this trend was not evident in Experiment I. Although intramuscular fat was slightly lower in Lot II than in the other lots, the entire group of animals used in the second experiment was not as fat as the group used in the first experiment.

Correlation coefficients are presented in table 4. Many of the same interrelationships were found as previously pointed out for the first experiment. However, in this experiment the water-binding capacity of the chilled muscle and pH of the fresh muscle were significantly correlated, but water-binding capacity of the chilled muscle failed to be significantly

TABLE 4. CORRELATIONS BETWEEN CERTAIN CHEMICAL AND PHYSICAL CHARACTERISTICS OF THE *GLUTEUS MEDIUS* MUSCLE

(EXPERIMENT II—HIGH SUCROSE RATION)

Chemical and physical characteristics	Muscle glycogen (fresh)	pH (fresh)	pH (chilled)	Lactic acid (chilled)	Color score	Wateriness score	% Expressible water (fresh)	% Expressible water (chilled)
pH (fresh)	—.087	.....	.....	.....	.....	.....	.....	.....
pH (chilled)	—.643**	0.253	.....	.....	.....	.....	.....	.....
Lactic acid (chilled)	0.544**	—.314	—.795**	.....	.....	.....	.....	.....
Color score	—.482*	0.448*	0.767**	—.667**	.....	.....	.....	.....
Wateriness score	—.495*	0.398*	0.640**	—.622**	0.901**	.....	.....	.....
Expressible water % (fresh)	—.375	0.126	.....	.....	.....	0.291	.....	.....
Expressible water % (chilled)	—.067	—.403*	—.084	0.392	—.319	—.104	—.146	.....
ΔExpressible water %	0.149	—.380	—.376	0.467*	0.571**	—.430*	—.552**	0.886**

* $P<.05$, $r>.396$.
** $P<.01$, $r>.505$.

associated with fresh glycogen, chilled pH, lactic acid, color score, and wateriness score. Fresh pH was significantly associated positively with color and wateriness scores, whereas those associations did not reach significance in the first experiment.

Discussion

The data indicate that a sudden and relatively short term change to a cold environment lowered fresh muscle glycogen, and therefore, resulted in a decreased lactic acid concentration in the chilled muscle. The physical effects of these changes were a definite darkening of muscle color, a trend toward higher ultimate pH, and an increased water-binding capacity. Lawrie (1960) has noted that there is a linear relationship between pH and lactic acid concentration in the muscle between pH 6.5 and 4.9. This finding has been supported by the high correlation coefficients found between chilled pH and lactic acid values.

Muscle with relatively constant myoglobin concentration has been shown to vary in color intensity with pH change (Lawrie, 1950; Hamm, 1953; Briskey *et al.*, 1959a). It was demonstrated by Hall *et al.* (1944) that the quantity of water imbided by beef muscle increased with increasing pH. Similarly, Lawrie *et al.* (1958) noted a severe exudative condition in pale pork muscle of low pH. Judge *et al.* (1958) found significant correlations between ultimate pH, color, and water-binding capacity in pork muscle. Briskey *et al.* (1959c) demonstrated that a high sucrose ration for swine increased fresh muscle glycogen and tended to decrease the water-binding capacity of chilled muscle.

One probable effect of a severe environmental change to cold temperature is instigation of epinephrine secretion which in turn promotes glycogen breakdown. Hedrick *et al.* (1957) found that epinephrine injection prior to slaughter resulted in reduced muscle glycogen at the time of death. Radouco-Thomas *et al.* (1959) also reported that epinephrine injection was effective in decreasing pH drop post-mortem, darkening muscle color, decreasing drip, and maintaining fiber integrity. Ante-mortem electric shock treatment has been shown to be effective in increasing pH of chilled pork muscle as well as in lowering dry matter and water loss during cooking (Lewis *et al.*, 1958).

Wismer-Pedersen (1959b) and Lawrie (1960) have found that water-binding capacity is more closely associated with pH at 45

min. to 1 hr. post-mortem than it is to ultimate pH. These observations indicate that rate of glycolysis may exert a greater influence than ultimate pH on the water-binding capacity of muscle. In support of this theory the data from Experiment II (high sucrose) show a significant correlation between pH of the fresh muscle and expressible water of the chilled muscle, but the association is not present when pH of the chilled muscle is compared to water-binding capacity. The fresh pH represents a measurement taken about 10 min. following cessation of blood circulation through the muscle. The significant correlations of fresh pH with color and wateriness scores as well as the trend toward lower initial pH in the second experiment indicate that post-mortem glycolysis is progressing at a more rapid rate than in the first experiment.

Comparison of the two experiments indicates that factors other than fresh glycogen content, chilled pH, and rate of glycolysis are important in determining the water-binding capacity of muscle. Fresh and chilled pH tended to be higher in Experiment I (normal ration) than in Experiment II (high sucrose ration). However, the percent expressible juice, both fresh and chilled, was highest in Experiment I, indicating a lower water-binding capacity than in Experiment II. A possible explanation of this apparent discrepancy has been advanced by Wismer-Pedersen (1959a). He postulated that increased hexose monophosphate levels in the muscle resulting from sugar feeding exerted an increased osmotic effect in raw muscle. Hexose monophosphate concentrations were not measured in the present experiments, but may have been increased in both fresh and chilled muscles due to sucrose feeding.

The control (Lot I) in the first experiment and the corresponding control (Lot II) in the second experiment presented the lowest percent expressible juice in fresh muscle; however, following a 24-hr. chilling period the percent expressible juice was as high or higher than in the treated lots. Swift *et al.* (1960) have reported that the glycogen level in fresh beef is positively correlated with the rate of post-mortem glycolysis. The increased water-binding capacity in fresh muscle of relatively high glycogen content might then be explained by the osmotic effect of a high concentration of the early products of glycolysis. The significantly decreased water-binding capacity of fresh muscle in Lot III (held 3 hr.) in the first experiment as compared to Lot I (control) and Lot II (held 10 min.) is another implication of the influence of the above mentioned osmotic effect since the 3-hr. holding period following treatment should allow time for complete degradation of excess glycogen breakdown products in the muscle.

Wismer-Pedersen (1959b) has stated that the incidence of low water-binding capacity is higher in gilts due supposedly to activation of adenosinetriphosphatase by progesterone. The data presented here indicate that the chilled muscles from gilts (Experiment II) had a higher water-binding capacity than those from barrows (Experiment I); however, the effect of sex cannot be evaluated in the present study because of other variables in the two experiments.

Summary

Market-weight swine were placed in cold water (0.5° C.) for 30–40 min. in an attempt to stimulate a severe environmental change. The extreme change in environment from warm to cold temperature decreased the initial muscle glycogen level with a resultant decrease in lactic acid concentration and an increase in color intensity of the chilled muscle. Water-binding capacity of the chilled muscle was not consistently affected. When the animals were held 3 hr. rather than 10–20 min. subsequent to treatment and prior to slaughter, there were no substantial changes in treatment response. Increased effects due to a 12-hr. holding period between treatment and slaughter were probably the result of a longer fasting period. The influence of rate of glycolysis and level of hexose monophosphates upon the water-binding capacity of the muscle have been discussed.

Literature Cited

A.O.A.C. 1955. Official Methods of Analysis (8th ed.) Association of Official Agricultural Chemists, Washington, D.C.

Barker, S. B. and W. H. Summerson. 1941. The colorimetric determination of lactic acid in biological material. J. Biol. Chem. 138:535.

Briskey, E. J., R. W. Bray, W. G. Hoekstra, R. H. Grummer and P. H. Phillips. 1959a. The chemical and physical characteristics of various pork ham muscle classes. J. Animal Sci. 18:146.

Briskey, E. J., R. W. Bray, W. G. Hoekstra, R. H. Grummer and P. H. Phillips. 1959b. The effect of various levels of exercise in altering the chemical and physical characteristics of certain pork ham muscles. J. Animal Sci. 18:153.

Briskey, E. J., R. W. Bray, W. G. Hoekstra, R. H. Grummer and P. H. Phillips. 1959c. The effect of

exhaustive exercise and high sucrose regimen on certain chemical and physical pork ham muscle characteristics. J. Animal Sci. 18:173.

Briskey, E. J., R. W. Bray, W. G. Hoekstra, P. H. Phillips and R. H. Grummer. 1960a. Effect of high protein, high fat and high sucrose rations on the water-binding and associated properties of pork muscle. J. Animal Sci. 19:404.

Briskey, E. J., W. G. Hoekstra, R. W. Bray and R. H. Grummer. 1960b. A comparison of certain physical and chemical characteristics of eight pork muscles. J. Animal Sci. 19:214.

Callow, E. H. 1937. The electrical resistance and micro structure of muscular tissue. Ann. Rpt. Food Invest. Bd. Dept. Sci. and Ind. Res. p. 46, London.

Grau, R. and R. Hamm. 1953. A simple method for the determination of water-binding in muscles. Naturwissenschaften 40:29.

Hall, J. L., S. E. Latschar and D. L. Mackintosh. 1944. Characteristics of dark cutting beef. Kan. Agr. Exp. Sta. Tech. Bul. 58, Part IV.

Hamm, R. 1953. Die wasserbindung des fleisches und ihre wirtschaftliche bedeutung. Deut. Lebensm. Rundschau. 49:159.

Hansen, R. G., W. J. Rutter and E. M. Craine. 1952. A nephelometric method for the determination of glycogen. J. Biol. Chem. 195:127.

Hedrick, H. B., D. E. Brady and C. W. Turner. 1957. The effect of ante-mortem stress on post-mortem beef carcass characteristics. Proc. 9th Res. Conf., Amer. Meat Inst. 9.

Judge, M. D., V. R. Cahill, L. E. Kunkle and F. E. Deatherage. 1958. Physical, chemical, and organoleptic relationships in fresh pork. J. Animal Sci. 17:1157.

Judge, M. D., V. R. Cahill, L. E. Kunkle and W. H. Bruner. 1959. Influence of some factors on pork muscle characteristics. J. Animal Sci. 18:448.

Lawrie, R. A. 1950. Some observations on factors affecting myoglobin concentrations in muscle. J. Agr. Sci. 40:356.

Lawrie, R. A. 1960. Post-mortem glycolysis in normal and exudative *longissimus dorsi* muscles of the pig in relation to so-called white muscle disease. J. Comp. Path. 70:273.

Lawrie, R. A., D. P. Gatherum and H. P. Hale. 1958. Abnormally low ultimate pH in pig muscle. Nature. 182:807.

Lewis, P. K., Jr., C. J. Brown and M. C. Heck. 1958. Effect of electric shock treatment and/or effect of feeding sugar prior to slaughter on certain carcass characteristics of swine. J. Animal Sci. 17:1150.

Ludvigsen, Jørgen. 1954. Undersøgelser over den såkaldte "muskeldegeneration" hos svin. Beretning fra Forsogslaborstoriet Udgivet af Statens Husdybrugsudvalg. 1:272.

Pork Carcass Evaluation Committee. 1952. Proc. 5th Ann. Reciprocal Meat Conf. p. 120. National Live Stock and Meat Board, Chicago.

Radouco-Thomas, C., C. Lataste-Dorolle, R. Zender, R. Busset, H. M. Meyer and R. F. Mouton. 1959. The anti-autolytic effect of epinephrine in skeletal muscle: nonadditive process for preservation of meat. Food Res. 24:453.

Swift, C. E., M. D. Berman and C. Lockett. 1960. Factors affecting the water retention of beef. II. Variations in some pH determinants among eight muscles. Food Tech. 14:74.

Steel, R. G. D. and J. H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill, New York.

Wierbicki, E. and F. E. Deatherage. 1958. Determination of water-holding capacity of fresh meats. J. Agr. and Food Chem. 6:387.

Wismer-Pedersen, J. 1959a. Some observations on the quality of cured bacon in relation to ante-mortem treatment. I-III. Acta. Agr. Scandinavica 9:69.

Wismer-Pedersen, J. 1959b. Quality of pork in relation to rate of pH change post-mortem. Food Res. 24:711.

FEEDING VALUE FOR FATTENING CATTLE OF CORN SILAGES TREATED TO INCREASE THEIR CONTENT OF ORGANIC ACIDS [1]

EARLE W. KLOSTERMAN, A. L. MOXON, RONALD R. JOHNSON, HAROLD W. SCOTT AND JACK VAN STAVERN

Ohio Agricultural Experiment Station

A POSSIBLE relationship between the organic acid content of corn silages and their feeding value for fattening cattle has been discussed in a previous publication (Klosterman *et al.*, 1960). It was also reported that the amounts of acetic and lactic acids in whole-plant and ground ear-corn silages could be markedly increased by the addition of small amounts of a neutralizing material at the time of ensiling. Cattle feeding experiments have indicated improvement in feed efficiency as a result of treating corn silages with pulverized, dolomitic limestone; however, these results were not conclusive. It was postulated that the relatively high magnesium content of the silages partially offset any beneficial effects which may have occurred. These experiments have been continued to determine the feeding value of whole-plant and ground-ear-corn silages treated with materials other than dolomitic limestone.

Procedure

Whole-Plant Corn Silage. Two identical concrete stave silos were filled on September 8 and 9, 1959 with well eared corn silage from the same field. One silo was filled in the usual manner without any additions. Approximately 0.5% high calcium ground limestone (36.66% calcium and 0.29% magnesium) and 0.5% urea were added to the chopped corn blown into the other silo. These materials were added by sprinkling over the top of the loaded wagons. They became well mixed with the corn as it was dropped off the back of the unloading wagons and blown into the silo.

Choice grade Hereford heifer calves were fed in this experiment. Two groups were fed in a barn without outside lots, two in a narrow open-sided shed with outside lots and two in outside lots without overhead protection. One lot in each of the three housing conditions was fed the control silage and one the limestone-urea treated silage. The heifers were assigned to lots at random within weight groups. One heifer in each of three lots was removed during the experiment because of pregnancy. The ration fed was designed to utilize the silages fully and to produce choice grade slaughter cattle. All lots were fed a specified amount of ground ear corn and full fed silage until they were eating 15 lb. of silage per head daily. They were then fed this amount of silage with ground ear corn full fed. Weights of the heifers and average daily rations consumed are given in table 1. Individual carcass weights and grades were obtained at the end of the experiment.

Ground Ear-Corn Silage. Ear-corn was picked with a standard picker and either stored in a concrete stave silo or artificially dried. The ensiled ear-corn was ground with a power take-off burrmill so as to at least crack most of the kernels at the time it was blown into the silo. The dry ear-corn was ground with a hammermill at the time it was fed. One percent high calcium, ground limestone and water were added to alternate loads of the ground high moisture corn which was separated from the untreated corn by a large sheet of plastic in the center of the silo. The ground limestone was added by sprinkling it over the loads of ground corn and the water was added through a hose at the blower. In order to determine dry matter losses during storage and feeding, the total amounts of dry matter stored by the three methods and the amounts of dry matter fed to the cattle were recorded.

Nine lots of seven choice grade Hereford steers each were fed in this experiment. The steers were assigned to lots at random within weight groups. Three lots were fed the limestone-water treated ear-corn silage, three lots the control silage and three lots the dry ear-

[1] Published with the approval of the Associate Director as Journal Article No. 6-61.

TABLE 1. FEEDING VALUE OF CONTROL AND LIMESTONE-UREA TREATED CORN SILAGE FOR GROWING, FATTENING HEIFERS

Replicate / Silage designation	Barn		Shed		Outside	
	Control	Treated	Control	Treated	Control	Treated
Number of heifers	13	13	14	14	13	14
Av. wt., Nov. 10, lb.	496	500	500	500	493	500
Av. wt., June 21, lb.	880	923	884	921	867	922
Av. daily gain, 224 days, lb.	1.72	1.89	1.71	1.88	1.67	1.89
Av. daily ration:						
Ground ear-corn, lb.	8.2	8.7	8.5	8.7	8.9	8.7
Soybean oil meal, lb.	1.0	1.0	1.0	1.0	1.0	1.0
Corn silage, lb.	13.3	14.1	13.8	14.6	13.9	14.7
Alfalfa hay, lb.	3.0	3.0	3.0	3.0	3.0	3.0
Salt, oz.	0.5	0.4	0.3	0.3	0.6	0.6
Minerals, oz.	0.1	0.2	0.3	0.3	0.4	0.5
Feed per cwt. gain, lb.:						
Ground ear-corn	477	459	497	461	537	462
Soybean oil meal	58	53	58	53	60	53
Corn silage	776	745	808	778	833	781
Alfalfa hay	175	160	176	160	181	160
Salt	2	1	1	1	2	2
Minerals	1	1	1	1	2	2
Carcass grade [a]	9.7	9.6	10.1	9.7	9.6	9.4
Dressing percentage	62.1	61.5	60.8	62.4	61.1	61.4

[a] High good, 9; low choice, 10.

corn. All lots were fed in the same barn with access to outside lots. Weights of the steers and average daily rations fed are given in table 2. Salt and minerals were self-fed. The mineral mixture fed with the dry corn and control silage consisted of two parts steamed bonemeal, two parts ground limestone and one part salt. The mineral fed with treated silage consisted of 4 parts steamed bonemeal and one part salt. All lots were fed specified amounts of good quality, clover-timothy mixed hay and solvent extracted soybean oil meal with corn full-fed according to appetite. Individual carcass grades and weights were obtained at a local packing plant.

Silage Analyses. Representative samples of

TABLE 2. FEEDING VALUE OF LIMESTONE-WATER TREATED AND CONTROL EAR-CORN SILAGES AND DRY EAR-CORN FOR GROWING, FATTENING STEERS

Ration designation / Replicate	Treated ear-corn silage			Control ear-corn silage			Dry ear-corn		
	1	2	3	1	2	3	1	2	3
Number of steers	7	7	7	7	7	7	7	7	7
Av. wt., Dec. 8, lb.	567	564	560	564	565	567	567	570	566
Av. wt., July 19, lb.	1021	1053	1005	993	959	958	972	987	1007
Av. daily gain, 224 days, lb.	2.03	2.18	1.99	1.93	1.76	1.75	1.81	1.86	1.97
Av. daily ration:									
Earn-corn silage, lb.	18.9	19.8	18.2	16.6	16.4	16.0	...	...	...
Dry earn-corn, lb.[a]	(10.1)	(10.6)	(9.8)	(9.9)	(9.7)	(9.5)	10.7	11.3	11.7
Soybean oil meal, lb.	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Mixed hay, lb.	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Salt, oz.	0.5	0.4	0.6	0.5	0.4	0.3	0.4	0.6	0.4
Minerals, oz.	1.1	1.1	1.1	1.1	1.3	1.1	1.4	1.1	1.4
Feed per cwt. gain, lb.									
Ear-corn silage	933	906	914	870	931	915	...	...	...
Dry ear-corn [a]	(500)	(486)	(490)	(517)	(553)	(543)	595	605	596
Soybean oil meal	74	69	75	78	85	86	83	81	76
Mixed hay	99	92	101	104	114	114	111	107	102
Salt	2	1	2	2	2	1	1	2	1
Minerals	3	3	3	4	5	4	5	4	4
Carcass grade [b]	11.1	11.4	11.4	11.0	10.6	10.0	10.1	10.4	10.6
Dressing percentage	63.2	63.9	63.7	62.6	61.8	60.4	61.8	62.0	62.6

[a] Converted to dry matter basis.
[b] Low choice, 10; average choice, 11.

TABLE 3. ANALYSES OF CONTROL AND TREATED SILAGES

	Number of samples	Percent moisture	pH	Percent acid, dry basis	
				Acetic	Lactic
Whole-plant corn silage					
Control	7	68.5	3.86	1.44	5.86
Treated [a]	7	66.6	4.48	1.83	10.42
Ground ear-corn silage					
Control	8	40.6	4.14	0.36	2.07
Treated [b]	8	46.4	4.30	0.75	4.66

[a] Approximately 0.5% high calcium ground limestone and 0.5% urea added at time of ensiling.
[b] 1.0% high calcium ground limestone and additional water added at time of ensiling.

whole-plant and ground ear-corn silages and dry ear-corn were taken for dry matter determinations. The silages were analyzed for organic acids as outlined by Klosterman *et al.* (1960).

Results and Discussion

Silage Analyses. Analyses of the ground ear-corn silages, table 3, indicate that approximately 6% additional water was added to the treated silage. The treatments used with either the whole-plant or ground ear-corn silages produced some increase in pH, a definite increase in acetic acid and a marked increase in lactic acid. These results are in agreement with those published previously.

Whole-Plant Corn Silage. Results of the 224-day feeding experiment, table 1, indicate a definite improvement in feeding value for the treated silage. In all three comparisons heifers fed the treated silage gained at a faster rate than those fed the control silage. These increased gains averaged 11% and proved to be highly significant, table 4. When the silage requirement per 100 lb. of gain was converted to an air-dry basis and added to the other feed requirements, cattle fed the treated silage required significantly less feed per unit of gain. There were no real differences in dressing percentages or carcass grades between heifers fed the two silages.

Heifers fed the treated silage ate slightly more corn and silage per head daily. The addition of urea to the treated silage increased its content of crude protein, hence, it is possible that the increased feed consumption and rate of gain may have been due to the higher level of crude protein in the treated silage ration. However, this does not seem likely since previous experiments with similar rations (Klosterman *et al.*, 1959) had shown no advantage in feeding larger amounts of protein than fed with the untreated silage in this experiment. Also, in the ear-corn silage experiment reported in the present publication, very similar increases were obtained with silage treated with limestone and water but no urea.

Ground Ear-Corn Silage. Results of this experiment, table 3, show an increased feeding value from the addition of 1% high calcium ground limestone and water to ensiled ground ear-corn. Steers fed the treated silage gained at a faster rate, required less feed per unit of gain, had a higher dressing percentage and graded higher in the carcass than steers fed the untreated silage or dry ear-corn. All of these differences were statistically significant (table 4).

In this experiment the weights and dry matter content of the total corn harvested and also the total amounts fed to the cattle were recorded. From these data it was possible to calculate the dry matter losses incurred in the different methods of feeding and storage. These losses would include those due to fermentations, spoilage and dust losses during grinding and feeding. These individual losses would be expected to be quite different for the ensiled and dry corn, however, it was possible to determine only the total loss. The total dry matter losses between the amounts stored and the amounts fed to the

TABLE 4. MEAN SQUARES—RATION, REPLICATE AND WITHIN REPLICATE EFFECTS

	Total	Between rations	Between replicates within rations	Within replicates
Whole-plant corn silage				
Degrees of freedom	80	1	4	75
Daily gain		0.6662**	0.0061	0.0364
Feed per cwt. gain		9,440.*	1,013.	
Dressing percentage		3.36	4.84	1.64
Carcass grade		2.00	0.50	1.57
Ground ear-corn silage				
Degrees of freedom	62	2	6	54
Daily gain		0.3815*	0.0594	0.0565
Feed per cwt. gain		11,666.**	374.	
Dressing percentage		23.98*	3.39	1.95
Carcass grade		5.50*	0.60	1.31

* Significant at probability level of 0.05.
** Significant at probability level of 0.01.

cattle were 16.8, 16.5 and 12.6% for the treated silage, untreated silage and dry ear-corn, respectively. With these losses and the amount of ear-corn dry matter required to produce a unit of gain, table 3, it was possible to calculate the amount of beef produced from a given yield of corn. These calculations showed that the net gain in pounds of beef produced from a given weight of harvested corn was 6.4% for the untreated silage and 15.8% for the treated silage as compared to the dry ground ears.

Results of these two experiments show a definite increase in the acid content and feeding value of corn silages treated at the time of ensiling with 1% high calcium, ground limestone or a mixture of equal parts limestone and urea. The results do not prove that the higher feeding values were due to the increased content of organic acids. It is possible that the improvement may have been due to the additives themselves. However, it was found in previous experiments (Bentley *et al.*, 1955) that corn silage treated with urea improved the performance of steers more than feeding an equivalent amount of urea mixed with dry, ground ear-corn. In consideration of the feed-replacement value of lactic acid (Johnson *et al.*, 1959; Klosterman *et al.*, 1960), the higher acid content of the treated silages appears to be a logical explanation for their higher feeding value.

Summary

The addition of approximately 0.5% each of high calcium, ground limestone and urea to whole-plant chopped corn at the time of ensiling increased the lactic acid content of the resultant silage by 78% on a dry basis. Treated and untreated silages were fed with soybean oil meal, alfalfa hay, minerals and dry, ground ear-corn to triplicate lots of growing-fattening heifers for 224 days. Heifers fed the treated silage gained significantly faster and required significantly less feed per cwt. gain than those fed the untreated silage.

Ear-corn, 40.6% moisture, was artificially dried, ensiled without treatment or ensiled with 1% high calcium, ground limestone and approximately 6% additional water. When fed, the treated silage contained 125% more lactic acid than the control silage. The two silages and dry corn were fed to triplicate lots of growing, fattening steers for 224 days. Steers fed the treated silage gained at a faster rate, required less feed per cwt. gain, had a higher dressing percentage and graded higher than steers fed the untreated silage or dry ear-corn. These differences were all statistically significant. Dry matter losses during storage and feeding were 16.8, 16.5 and 12.6% for the treated silage, untreated silage and dry ear-corn, respectively.

Literature Cited

Bentley, Orville G., Earle W. Klosterman and Paul Engle. 1955. The use of urea to increase the crude protein content of corn silage for fattening steers. Ohio Agr. Exp. Sta. Res. Bul. 766.

Johnson, Ronald R., Earle W. Klosterman, John E. Moore and Harold W. Scott. 1959. The effect of corn steepwater and lactic acid on animal performance and digestibility when added to natural and purified ruminant rations. J. Animal Sci. 18:1519 (Abstr.)

Klosterman, Earle W., Ronald R. Johnson, Harold W. Scott, A. L. Moxon and Jack Van Stavern. 1960. Whole plant and ground ear corn silages, their acid content, feeding value and digestibility. J. Animal Sci. 19:522.

Klosterman, Earle W., A. L. Moxon and V. R. Cahill. 1959. Effect of stilbestrol and amount of corn silage in the ration upon the protein requirement of fattening steer calves. J. Animal Sci. 18:1243.

RELATIONSHIP OF GAMMA-RAY MEASUREMENTS TO THE LEAN CONTENT OF HAMS

R. KULWICH,[1] L. FEINSTEIN,[1] C. GOLUMBIC,[1] R. L. HINER,[2] W. R. SEYMOUR,[2] AND W. R. KAUFFMAN [2, 3, 4]

U. S. Department of Agriculture

ONE important problem in marketing livestock and meat is evaluating the lean content of intact animals and meat cuts derived from them. An objective method that could provide a sufficiently accurate estimate of the lean content of intact meat cuts would be useful, provided the cost of the equipment and the time required for the measurement were not excessive.

A preliminary study involving gamma-ray measurements of hams was carried out at the Los Alamos Scientific Laboratory (Kulwich *et al.*, 1958). This suggested that a relationship exists between potassium-40 concentration and the fat-free lean content. Zobrisky *et al.* (1959) reported research involving potassium-40 gamma-ray measurements with live hogs which indicated that the technique may be useful for determining protein:fat ratios. Kirton *et al.* (1960) reported a study in which potassium-40 gamma-ray measurements were made of ten live unwashed and washed lambs and of their carcasses. They found that the correlation (r=0.51) between estimated potassium content and percent carcass lean was not significant. The correlations of estimated potassium content of the live unwashed lamb with percent carcass fat (r=—.79) and percent bone (r=0.86) were both highly significant.

At this laboratory, gamma-ray measurements are being studied in relation to the physical and chemical composition of a wide variety of meat samples. The purpose of the present study was to obtain data on the relationship of gamma-ray measurements to the composition of hams.

Materials and Methods

One fresh ham was used from each of the following: ten Yorkshire barrows, eight Yorkshire gilts, seven Duroc barrows, and nine Duroc gilts. All animals were kept in drylot after 8 weeks of age. They all received the same rations, consisting of varying proportions of a protein-mineral mix and corn. For the first 6 weeks after weaning, a 30% level of the protein-mineral mix was fed, with the balance consisting of ground yellow corn. During the next 6-week period a 25% level of the protein-mineral mix was fed, and after this a 17% level of the protein-mineral mixture was fed, with ground yellow corn making up the balance of the ration. The slaughter weights of these animals ranged from 188 to 223 lb.

After chilling, the carcasses were cut and gamma-ray measurements were made with one ham from each carcass. Gamma-ray emission was measured by the use of a low level counting facility, type NE 8105 [5] manufactured by Nuclear Enterprises (G.B.) Ltd. of Edinburgh, Scotland. The general characteristics of the instrument used have recently been described (Pringle and Kulwich, 1961). Concurrent measurements of gamma radioactivity were made at two channel settings. The upper channel primarily indicated potassium-40 gamma-rays with a small spill of counts arising from cesium-137, a fission product which occurs widely in foods (Anderson *et al.*, 1957). The lower channel primarily indicated cesium-137 gamma rays, with some spill of counts arising from potassium-40. Upper channel background was about 4000 counts per minute, with a lower channel background of around 5000 counts per minute. Standards consisting of known amounts of cesium-137 in distilled water and of potassium chloride mixed with granulated sugar were used to calibrate counting efficiency and the extent to which counts from cesium-137 and potassium-40 spilled over into the upper and lower channels, respectively. On the basis of data obtained with standards, mathemati-

[1] Agricultural Marketing Service, Beltsville, Maryland.
[2] Agricultural Research Service, Beltsville, Maryland.
[3] The technical assistance of M. F. Combs, A. A. Collins, B. E. Dennard, and T. Jackson is gratefully acknowledged.
[4] A report on this research was presented at the 52nd annual meeting of the American Society of Animal Production, Chicago, Illinois, November 25–26, 1960.

[5] Mention of specific instruments or trade names is made for identification purposes only and does not imply any endorsement by the U. S. Government.

cal corrections were applied so that the net potassium-40 and cesium-137 gamma-ray emission were calculated. While the gamma-ray emissions of the samples were expressed in terms of cesium-137 and potassium-40 gamma rays, high resolution gamma-ray spectrum measurements which could rule out the presence of other gamma-ray emitters were not made. If other gamma-ray emitters were present, their emissions would have been reflected in terms of their contributions to the channel settings used for cesium-137 and potassium-40.

Each sample was counted for 40,000 preset counts six times, with background measurements before and after each count of 20,000 preset counts. From about 50 to 54 minutes counting time was spent on each ham. The standard deviation of the upper channel net counting rate determination for these hams ranged from 2.4 to 4.6% of the net counting rate observed. If both hams from each carcass had been measured together, the relative standard deviation of the net counting rate measurement would have been considerably lower. The 2.4% standard deviation was obtained with a 17.2 lb. ham containing 11.7 lb. of separable lean, while a 13.0 lb. ham containing 6.5 lb. of separable lean provided the 4.6% standard deviation. With some of these hams, delay before dissection resulted in appreciable shrinkage. For these samples a correction was applied so that 90% of the weight loss was added to the observed separable lean weight and 10% to the observed separable fat weight. These adjustments for shrinkage are based on unpublished data of the Animal Husbandry Research Division, U. S. Department of Agriculture.

After gamma-ray measurements were made, the hams were dissected with a knife to separate the bone, skin, separable lean, and separable fat. The standard deviations for the lower channel net counting rate determination was greater than that observed for the upper channel for all samples so that the cesium-137 estimate had a larger counting error than did the potassium-40 estimate. The gamma-ray emissions of a 20-lb. composite sample of skin and a 22-lb. composite sample of bone from these hams were measured. Fat and lean portions from each ham were ground separately, once through a coarse plate of a meat

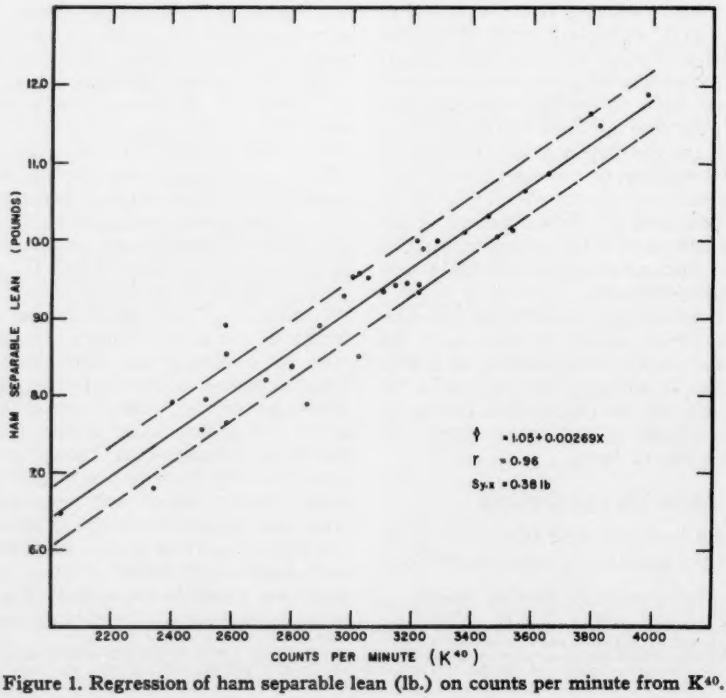


Figure 1. Regression of ham separable lean (lb.) on counts per minute from K^{40}.

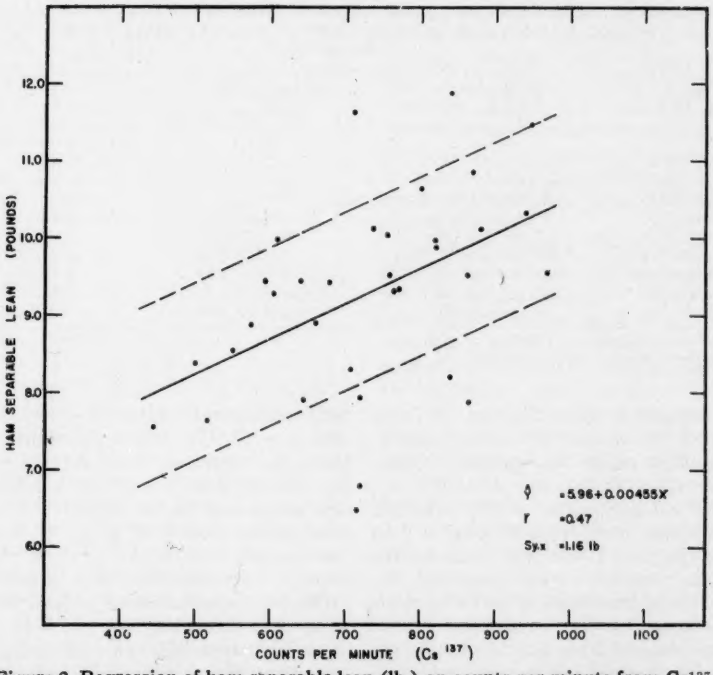


Figure 2. Regression of ham separable lean (lb.) on counts per minute from Cs^{137}.

grinder and three times through a fine plate (about 1/16 inch diameter holes). Ether extract content was determined for separable lean and separable fat samples, using an adaptation of the A.O.A.C. (1955) method.

Results and Discussion

Separable lean of the ham was highly correlated (r=0.96) with potassium-40 activity (figure 1). The amount of separable lean per ham ranged from 6.5 to 11.7 lb., averaging 9.27 lb. The equation for the regression of separable lean on counts per minute from potassium-40 per ham was $Y=1.05+0.00269X$, with a sample standard deviation from regression (Snedecor, 1956) of 0.38 lb. of separable lean. The 95% confidence limits for the predicted separable lean were ±0.78 lb. or ±8.4% of the mean value for separable lean. Muldowney *et al.* (1957) found a highly significant correlation (r=0.90) between total exchangeable potassium and the lean body mass of 30 human subjects ranging from 18 to 81 years in age. The 95% confidence limits for the predicted exchangeable potassium content were equal to ±25% of the mean value.

The correlation (r=0.47) between separable lean and cesium-137 was rather low but significant (figure 2). This relationship would not be useful for predicting lean content, since the cesium-137 content was associated with only 22% of the variation in ham separable lean. The regression equation was $Y=5.96+0.00455X$, with a sample standard deviation from regression of 1.16 lb. of separable lean. An analysis of the relationships between ham weight and separable components as well as between various gamma-ray measurements and separable ham components is presented in table 1. Of the four predictors of total amount of separable lean which were evaluated, net counts per minute from K^{40} per ham gave an estimate with the smallest sample standard deviation from regression (0.38 lb.). The prediction of total separable lean from the regression on upper channel net counts per minute per ham had a very similar sample standard deviation from regression (0.40 lb.). For this regression, upper channel net counts were used with no adjustment for

TABLE 1. RELATIONSHIPS BETWEEN HAM WEIGHT AND SEPARABLE COMPONENTS AND BETWEEN VARIOUS GAMMA-RAY MEASUREMENTS AND SEPARABLE COMPONENTS (34 HAMS)

Dependent variable (Y)	Independent variable (X)	Regression equation (Y=)	r[a]	$S_{y \cdot x}$[b]
Separable lean (lb.)	Ham weight (lb.)	1.001X−6.25	0.88	0.63 lb.
Separable lean (lb.)	K^{40}, net cpm[c]/ham	0.00269X+1.05	0.96	0.38 lb.
Separable lean (lb.)	Upper channel net cpm/ham	0.0184X+0.56	0.95	0.40 lb.
Separable lean (lb.)	Cs^{137}, net cpm/ham	0.00455X+5.96	0.47	1.16 lb.
Fat-free separable lean (lb.)	K^{40}, net cpm/ham	0.00260X+0.67	0.96	0.37 lb.
Percent separable lean	K^{40}, net cpm/lb. ham	0.235X+13.4	0.87	2.5%
Percent separable lean	Ham weight (lb.)	2.620X+18.9	0.59	4.2%
Percent separable fat	K^{40}, net cpm/lb. ham	−.250X+76.2	−.86	2.8%
Percent separable fat	Ham weight (lb.)	−2.850X+71.3	−.59	4.4%

[a] 0.44 required for significance at P=0.01.
[b] Sample standard deviation from regression.
[c] Counts per minute.

the small cesium-137 contribution (ranging from 1.4 to 2.5% of total net counts) and no corrections were made for gamma-ray absorption as a function of sample weight.

The ether extract content of the separable lean from these hams ranged from 4.1 to 12.8%. On the basis of chemical analyses, the separable lean content of each ham was expressed on a fat-free basis. The mean value for fat-free separable lean weight was 8.6 lb., with values ranging from 5.8 to 11.3 lb. On the basis of this regression, fat-free separable lean content could be estimated with a sample standard deviation from regression of 0.37 lb.

The coefficients of correlation between K^{40} emission and percent separable lean or percent separable fat were lower than those for K^{40} emission with total separable lean content. This probably reflects the effect of the part to whole relationship in the latter correlation. The sample standard deviation for predicted percent separable lean based on the regression with ham weight was about 68% larger than the corresponding value based on the regression with net counts per minute from K^{40} per pound of ham (4.2% vs. 2.5%). The trend was similar with the regressions for predicting percent separable fat. The percentage of separable lean in these hams ranged from 47 to 68% of the weight of the intact ham, averaging 59.7%. Percent separable fat ranged from 17 to 42%, with a mean value of 27.1%.

The 34 hams of this study may be sorted into groups which differ in percent separable lean on the basis of the values for net counts per minute from K^{40} per pound of ham. An appreciable amount of overlapping would be expected between adjacent groups because of the size of the sample standard deviation from the regression used for the prediction. To illustrate this, we may consider sorting the hams into three categories. If we designate as the "low lean" group all hams giving readings of 173 net counts per minute per pound (corresponding to a predicted value of 54.0% separable lean) or less, we find that three hams ranging from 46.9 to 52.1% in measured separable lean content fall into this category. Hams giving readings of 203 net counts per minute per pound (corresponding to a predicted value of 61.0% separable lean) or more will be designated as "high lean" hams. Thirteen hams, ranging from 57.2 to 68.3% in measured separable lean content, fall into this category. The "medium lean" category, hams giving readings of from 174 to 202 net counts per minute per pound, included 18 hams ranging from 52.7 to 63.6% in measured separable lean content. Six hams of the "high lean" group overlapped with the "medium lean" group in measured percent of separable lean. The mean values for measured percent separable lean for the three groups were 49.4%, 58.4% and 63.6% for the "low lean", "medium lean", and "high lean" groups, respectively.

The results of many of the gamma-ray measurements made are summarized in table 2. The values shown for the swine rations are the average for the three rations used. The average cesium-137/potassium-40 ratio observed for the three swine rations was 0.25. The average cesium-137/potassium-40 gamma-ray ratio for the 34 intact hams was also 0.25. Anderson *et al.* (1957) reported a cesium-137/potassium-40 gamma-ray ratio of

TABLE 2. SUMMARY OF GAMMA-RAY MEASUREMENTS

Item	Mean	Coefficient of variation
	net cpm/lb.[a]	%
Ham K^{40}/separable lean	331	4.8
Ham Cs^{137}/separable lean	82	18.3
Ham K^{40}/fat-free separable lean	355	4.7
Ham K^{40}/fat-free matter in separable lean and separable fat	297	5.5
Ham bone K^{40}	149	...
Ham bone Cs^{137}	39	...
Ham skin K^{40}	47	...
Swine rations Cs^{137}	136	...
Swine rations K^{40}	550	...

[a] Counts per minute per pound.

0.30 in fresh pork hams of the spring 1956 period. The animals in the present study were slaughtered in the spring of 1960.

In considering these data, it should be noted that the first item was derived by dividing the total counts per minute from potassium-40 per ham by the value for pounds of separable lean. It is not to be inferred that the resulting mean value, 331 counts per minute, represents the potassium-40 emission from a pound of separable lean. This would only be true if separable lean were the only ham component containing potassium-40. On the basis of measurements of composite samples, it was found that a pound of ham bone emitted 149 counts per minute, and a pound of ham skin 47 counts per minute of potassium-40. On the average, bone comprised 9.5% of the intact ham weight and emitted 7.2% of potassium-40 gamma-rays. Skin comprised 3.8% of the intact ham weight on the average, and emitted 0.9% of the total potassium-40 gamma-rays. It should be noted that the composite bone sample was not completely devoid of meat. In addition to this, we were not able to analyze the sample to determine if gamma-ray emitters other than potassium-40 and cesium-137 were present. The value for potassium-40 gamma-ray emission of ham bone should be considered in the light of these considerations. An average of 91.9% of the total ham potassium-40 was associated with the separable lean and separable fat portions.

The second, third, and fourth items in table 2 were calculated in a manner analogous to the first item. A comparison of the coefficients of variation in table 1 reflects that there is considerably more variability in the cesium-137 emission divided by pounds of separable lean in the ham than was found in the case of potassium-40 emission. The ether extract content (fat and other ether soluble materials) of separable ham lean varied from 4.4% to 12.8%. The coefficient of variation for counts per minute of potassium-40 divided by the value for pounds of fat-free separable lean was 4.7%. This is close to the 4.8% value obtained when total separable lean was considered.

The relationship between potassium-40 gamma-ray emission and separable lean content of the hams studied was highly significant. However, the use of this technique has limitations as well as advantages. There is an appreciable amount of error in the prediction. With samples such as these hams, which were far smaller than the capacity of the gamma-ray detector, a rather long counting time is required to obtain a sufficiently low standard deviation for the net counting rate determination. The counting equipment is costly and complex. However, equipment costs may be reduced and performance improved in the future. The gamma-ray measurement technique has an advantage in that the sample is not destroyed or altered by measurement. Information on gamma-ray emitters in addition to potassium-40 can be obtained concurrently. This could prove useful in surveillance of foodstuffs for their content of gamma-ray emitters.

Additional samples need to be evaluated to determine if the relationship observed in this study will be found in meat cuts from animals raised under different conditions. Such research is now underway at this laboratory.

Summary

Measurements were made of the gamma-ray emission of single hams from 34 hogs, using a sensitive low level gamma-ray detector. The hams were then separated by physical dissection into separable lean, separable fat, bone, and skin so that the gamma-ray measurements could be evaluated as to their usefulness for predicting ham composition. The separable lean content of the hams ranged from 6.5 to 11.7 lb., averaging 9.27 lb. Net counts per minute from potassium-40 were highly related (r=0.96) to pounds of separable lean. The sample standard deviation from regression was 0.38 lb. of separable lean. There was a much lower degree of correla-

tion (r=0.47) between net counts per minute from the fission product cesium-137 and pounds of separable lean. The average ratio of cesium-137/potassium-40 gamma ray emission was the same for the rations fed (0.25) as for the intact hams.

Literature Cited

Anderson, E. C., R. L. Schuch, W. R. Fisher, and W. Langham. 1957. Radioactivity of people and foods. Science 125:1273.

A.O.A.C. 1955. Official Methods of Analysis (8th ed.) Association of Official Agricultural Chemists, Washington, D.C.

Kirton, A. H., A. M. Pearson, E. C. Anderson, and R. L. Schuch. 1960. The use of naturally occurring K^{40} to determine the carcass composition of live sheep. J. Animal Sci. 19:1237 (Abstr.).

Kulwich, R., L. Feinstein, and E. C. Anderson. 1958. Correlation of potassium-40 and fat-free lean content of hams. Science 127:338.

Muldowney, F. P., J. Crooks, and M. M. Bluhm. 1957. The relationship of total exchangeable potassium and chloride to lean body mass, red cell mass and creatinine excretion in man. J. Clin. Invest. 36:1375.

Pringle, D. H. and R. Kulwich. 1961. K^{40} gammas give estimate of lean meat content. Nucleonics 19:74.

Snedecor, G. W. 1956. Statistical Methods (5th ed.) The Iowa State College Press, Ames, Iowa.

Zobrisky, S. E., H. D. Naumann, A. J. Dyer, and E. C. Anderson. 1959. The relationship between the potassium isotope, K^{40} and meatiness of live hogs. J. Animal Sci. 18:1480 (Abstr.).

APPARATUS FOR COLLECTING EXCRETA FROM GRAZING CATTLE

A. L. Lesperance and V. R. Bohman [1]
University of Nevada, Reno

Bassett (1952) and Budtz-Olsen *et al.* (1960) have devised an apparatus for collection of urine from the grazing animal. Erwin *et al.* (1959) and Cook *et al.* (1952) described harnesses and bags for the separate collection of feces and urine from grazing wethers.

Gorski *et al.* (1957) reviewed many of the procedures available for separating urine and feces in cattle and stated that it was impossible to use these methods for separate collections unless the animal was stanchioned. These investigators devised a system for quantitatively collecting excreta from female animals in which a separator was attached over the vulva for urine collections and the feces were collected posterior to the urine collection container. With this apparatus, it appeared necessary to remove the excreta three or four times daily. Although it was indicated that this equipment could be used for pasture studies, the frequent removal of the excreta would be difficult under pasture conditions and almost impossible when animals are grazing western range lands. The authors stated that unless properly adjusted, poor separation of feces and urine was likely to occur with this apparatus.

Urine collection has presented the greatest problem in quantitatively separating the excreta. Cunningham *et al.* (1955) described a method for collecting urine from restrained cows through the use of an inflatable catheter.

The apparatus described in this paper employs an inflatable urethral catheter for urine collection in conjunction with a fecal bag modified for grazing animals.

Construction

Fecal Collection Bag. The fecal collection bag and harness as described by Garrigus and Rusk (1939) were used with certain modifications. No connecting strap was used between the girth strap and the strap located anterior to the shoulders. The bags were constructed of 16 oz. vinyl coated nylon which was lighter, stronger, more waterproofed and easier to clean than the heavy waterproofed duck previously used. The tail of the animal was included within the fecal sack to minimize loss of fecal material and to prevent injury to the ventral portion of the tail by close adjustment.

Urine Collection Container. An inflatable urethral catheter as described by Cunningham *et al.* (1955) was used (figure 1). This catheter was clamped onto a modified inner tube (figure 2). A one-way valve was inserted into the tube to prevent unusual or abnormal pressure on the bladder of the animal, due to a back-flow of urine from the tube. The urine container was a 8 or 9 x 20 in. truck tube with the valve-stem changed from the inside to the outside periphery. The tube was encased in a light flat canvas bag approximately 36 in. in circumference. Two 10 to 12 in. zippers opening in opposite directions were placed on one edge to facilitate the removal of the tube.

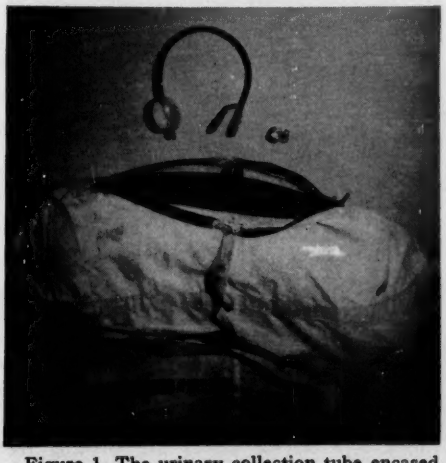


Figure 1. The urinary collection tube encased in the supporting canvas with zippers open. Note the inflated catheter.

[1] Department of Animal Husbandry. This study was supported in part by a research grant from the Soil and Water Conservation Research Division, A.R.S., USDA and in cooperation with the regional project W-34, Range Livestock Nutrition. The authors wish to acknowledge the assistance of B. Peterson, University of Nevada Agriculture Editor, in obtaining the pictures illustrating this apparatus.

Four pairs of canvas straps 1 x 6 in. were placed on the bag at 90 degree intervals to hold the bag in place during collection. The anterior pair was attached to the dorsal portion of the girth strap, the lateral pairs were attached to the harness on each side and the caudal pair was attached to the grommets in the fecal collection bag. This also served to protect the catheter from catching on brush and fencing. Two girth straps were also attached to the bag on each side. These straps went around the animal to aid in holding the bag in place (figure 3).

Assembling. After the fecal bag is attached as described by Garrigus and Rusk (1939), the urine collecting tube is completely deflated and placed inside the canvas supporting bag. The modified valve stem is centered and held in place between the two zippers. After the catheter is inserted and inflated, the canvas bag is placed on the animal's back and secured in place. The catheter is then attached to the tube stem (figure 2) and the caudal pair of straps tied.

Operation

The urine pressure in the bladder is sufficient that the flow of urine into the collecting tube is accomplished easily. The capacity of the deflated tube eliminates the necessity for an air vent without pressure building up in the urine container. When samples are collected, the catheter is clamped shut, the canvas sack and tube removed and drained into a suitable container. Fecal collections are made according to the description of Garrigus and Rusk (1939). Occasionally a catheter may break while in use, and in the case of stress involving diuresis, the urethra may dilate, permitting the animal to void the catheter. These situations are infrequently encountered.

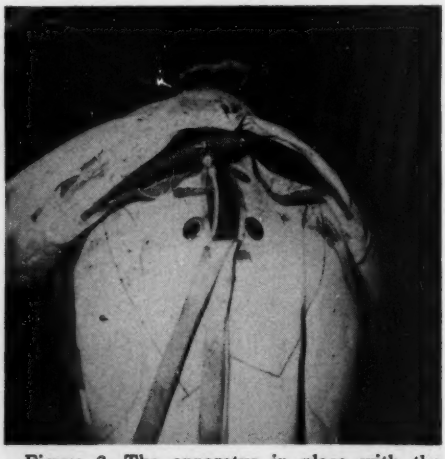


Figure 2. The apparatus in place with the zipper open on the canvas bag showing the catheter in place and attached to the tube. A one-way glass valve connects the urethral catheter to the collecting tube.

Figure 3. All portions of the apparatus in place as used under grazing conditions.

This apparatus permits a large portion of the daily (24 hr.) excreta to be carried easily by the animal without apparent discomfort. The total weight of the entire apparatus is 18 lb. The apparatus described was fabricated in this laboratory with the aid of a local awning company.[2] Urine is collected from the grazing animal without contamination with vaginal secretions or feces. Fecal contamination with urine is also eliminated. This equipment was used on one animal for 20 days continuously without adverse effects. No serious adverse effects were noticed with any of the animals. Occasionally a slight inflammation of the genital organs occurred which responded readily to treatment.

This apparatus has been used successfully for digestion and balance studies under a wide variety of conditions. These include 32 collections in drylot (figure 3), 32 collections on improved pasture and 17 collections under semi-desert and sagebrush-grass type range. The balance studies have involved nitrogen, phosphorus molybdenum, copper and sulphur. If copper balances are conducted, it is nec-

[2] Quimby's Reno Awning and Blind Factory. 735 W. Third St., Reno, Nevada.

essary to replace the normal copper containing stem in the urine collecting tube with glass. If not, urinary copper was found to increase as much as tenfold overnight. No other problems of contamination were noted with this equipment although all of the elements involved in the above balance studies were critically checked. Collections were normally made twice daily under drylot and improved pasture conditions and once daily while the animals grazed range lands.

Summary

A portable apparatus that quantitatively collects feces and urine from cows and heifers without contamination is described. This equipment employs an inflatable urethral catheter connected to a collecting container carried on the back of the animal. A vinyl-coated fecal collecting bag is also used. This equipment is simple, relatively inexpensive and has been successfully tested under a wide variety of conditions.

Literature Cited

Bassett, E. G. 1952. Apparatus for continuous collection of urine from the grazing ewe. New Zealand J. Sci. Tech. 34:76.

Budtz-Olsen, O. E., H. C. Dakin and R. J. H. Morris. 1960. Method for continuous urine collection from unrestrained wethers and other large animals. Australian J. of Agr. Res.

Cook, C. W., L. A. Stoddart and L. E. Harris. 1952. Determining the digestibility and metabolizable energy of winter range plants by sheep. J. Animal Sci. 11:578.

Cunningham, H. M., G. L. Frederick and G. J. Brisson. 1955. Application of an inflatable urethral catheter for urine collection from cows. J. Dairy Sci. 38:997.

Erwin, E. S., J. W. Blair and H. M. Page. 1959. Excreta collection apparatus for wethers. J. Animal Sci. 18:935.

Garrigus, W. P. and H. P. Rusk. 1939. Some effects of the species and stage of maturity of plants on the forage consumption of grazing steers of various weights. Ill. Agr. Exp. Sta. Bul. 454.

Gorski, J., T. H. Blosser, F. R. Nardock, A. S. Hodgson, B. K. Soni and R. E. Erb. 1957. A urine and feces collecting apparatus for heifers and cows. J. Animal Sci. 16:100.

PERFORMANCE INDEX FOR LIFETIME PRODUCTION

S. S. Y. Young and G. M. Tallis [1]

Division of Animal Genetics, C.S.I.R.O., McMaster Laboratory, Glebe, Sidney, N.S.W.

VARIOUS methods of selecting breeding animals for several characters have been investigated by a number of workers (Fairfield Smith 1936; Hazel and Lush, 1942; Hazel, 1943; Young and Weiler, 1960) and different techniques such as tandem selection, independent culling levels and index selection have been used. Relatively little attention, however, has been given to the theory of selection for lifetime production. Lush (1945) discussed the use of the estimate of repeatability in predicting the producing ability of cows, but no work has been reported on the theory of selection for lifetime performance on more than one trait.

Genetic gains through selection, measured per unit of time, are governed by the generation interval as well as by the selection differentials and levels of heritability of the characters under selection. For farm animals such as sheep and dairy cattle, where production can be measured on a number of occasions and where the generation intervals are long, it is possible to imagine a number of situations where lifetime performance is relatively more important than its additive genetic merit. For example, when economic weights of production characteristics are stable over short but unstable over long periods, or when the estimates of repeatability are much higher than those of heritability, it may be worthwhile to select for superiority in lifetime performance.

It is the aim of this paper to show that the theory of the selection index (Fairfield Smith, 1936; Hazel, 1943) can be used to develop an index for lifetime production, which has been called a "performance index". This index should be used in selection based on one record for each trait.

Theory

Performance Index. The theory of the performance index can be adapted directly from that of the selection index. If several traits, $X_1, X_2, \ldots . X_n$, are under selection the observed value of X_i, x_i, can be written as:

$$x_i = g_i + f_i$$

where g_i is due to genetic and f_i to environmental factors. A selection index in the form of:

$$Z = \Sigma_i \, b_i \, x_i \qquad (1)$$

can then be constructed. The b_i values in the selection index are calculated such that Z can best discriminate between the total breeding values of animals $H = \Sigma_i \, a_i \, g_i$, the a_i being the predetermined economic weight of X_i. If x_i is rewritten as:

$$x_i = s_i + e_i$$

where s_i is due to factors causing permanent differences among animals and e_i to temporary environmental effects (s_i and e_i are assumed to be statistically independent) a performance index analogous to the selection index can be constructed. The performance index can be written as:

$$W = \Sigma_i \, k_i \, x_i \qquad (2)$$

where k_i are values calculated such that W can best discriminate among the total production values, $M = \Sigma_i \, a_i \, s_i$. Our problem is to find the appropriate values of k_i.

If W has variance σ^2_W, then the gain in lifetime production value per animal after selection is:

$$\Delta M = B_{M.W} \, \sigma_W \, I \qquad (3)$$

where $B_{M.W}$ is the regression coefficient of M on W, and I is the selection differential of W in standard deviation units.

To obtain the greatest gain in M, we require therefore to maximize $\triangle M$ for any given selection differential I, which is equivalent to maximizing $B_{M.W} \, \sigma_W$. By partial differentiation of the latter expression with re-

[1] Thanks are due to Professor P. R. McMahon of the School of Wool Technology, University of New South Wales who suggested to us the subject of this investigation, to Miss Helen Newton Turner of the Division of Animal Genetics for her comments on the manuscript and to Miss Turner and Mr. C. H. S. Dolling of the same Division for making available the data used in the numerical example.

spect to the k_i and equating to zero, the optimum k values can be calculated as:

$$k=P^{-1}\,S\,a, \text{ or } k_i=\Sigma_{qr}\,P^{iq}\,S_{qr}\,a_r,$$

$$i=1, 2, \ldots n \qquad (4)$$

where: k=column vector of k_i
P^{-1}=inverse matrix of P with elements P^{ij}
P_{ij}=phenotypic covariance between x_i and x_j
S=matrix of S_{ij}
S_{ij}=covariance between s_i and s_j
a=column vector of a_i.

Matrices P and a are well known and S may be constructed by estimates of the between-animal components S_{ij} calculated in the usual manner (table 1).

An interesting special case of (4) is obtained when the traits under selection are independent. In this instance we have $S_{ij}=P^{ij}=0$ and $P^{ii}=\frac{1}{P_{ii}}$ so that:

$$k_i=a_i\frac{S_{ii}}{P_{ii}}$$

The quantity $\frac{S_{ii}}{P_{ii}}$ is generally known as the repeatability (t) of the trait X_i. When one record for each trait is available on the animals to be selected the index reduces to:

$$W=\sum_{i=1}^{n} a_i\,t_i\,x_i \qquad (5)$$

Equation (5) is also useful as an approximate index when the phenotypic correlations between traits are small.

As a decision will frequently have to be made between this performance index and the standard selection index, it is of interest to note that the correlation between the two may be written as:

$$r_{WZ}=\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{b_i\,k_j\,P_{ij}}{\sigma_Z\,\sigma_W} \qquad (6)$$

where σ_Z is the standard deviation of the selection index.

TABLE 1. ANALYSIS OF VARIANCE AND COVARIANCE WHEN n ANIMALS ARE MEASURED FOR TWO TRAITS X_i AND X_j IN q YEARS

Source of variation	Degrees of freedom	Variance [a] and covariance components
Between years	q−1	$E_{ij}+nY_{ij}$
Between animals	n−1	$E_{ij}+qS_{ij}$
Years x animals	(q−1) (n−1)	E_{ij}

[a] For variance i=j.

Expected Phenotypic and Genetic Gains. It is always desirable to predict both the phenotypic and genetic changes in individual traits which are likely to follow the use of any index, and in the present case it is also useful to compare the total economic gains, so that a choice can be made between the selection and performance indices. The following formulas for these gains may be verified.

(i) Expected gains by using W:

(1) (a) Gain in M,

$$\Delta M=B_{M.W}\,\sigma_W\,I=\sigma_W\,I \qquad (7)$$

(b) Gain in s_i,

$$\Delta s_i=\Sigma_j\frac{k_j\,S_{ij}}{\sigma_W}\,I \qquad (8)$$

(2) (a) Gain in H,

$$\Delta G_W=\Sigma_i\,\Sigma_j\frac{a_i\,k_j\,G_{ij}}{\sigma_W}\,I \qquad (9)$$

where G_{ij} is the covariance between g_i and g_j

(b) Gain in g_i,

$$\Delta g_{iW}=\Sigma_j\frac{k_j\,G_{ij}}{\sigma_W}\,I \qquad (10)$$

(ii) Expected gains by using Z:

(1) (a) Gain in H,

$$\Delta G=\sigma_Z\,I \qquad (11)$$

(b) Gain in g_i,

$$\Delta g_i=\Sigma_j\frac{b_j\,G_{ij}}{\sigma_Z}\,I \qquad (12)$$

(2) (a) Gain in M,

$$\Delta M_Z=\Sigma_i\,\Sigma_j\frac{a_i\,b_j\,S_{ij}}{\sigma_Z}\,I \qquad (13)$$

(b) Gain in s_i,

$$\Delta s_{iZ}=\Sigma_j\frac{b_j\,S_{ij}}{\sigma_Z}\,I \qquad (14)$$

Numerical Illustration

Data from 62 unselected Merino ewes of a medium Peppin strain, run at the National Field Station "Gilruth Plains" Cunnamulla were used in this illustration. The ewes were born in 1948 in the "Control Group" described by Turner (1958), and records of clean wool weight (X_1) and crimps per inch (X_2) for each animal were first taken at 15–16 months of age on 10–11 months' wool growth. Observations of these characters were made annually for four consecutive years after the first sampling. From these data a performance index can be constructed for the selection of similar ewes at 15–16 months of age.

TABLE 2. ANALYSES OF VARIANCE AND COVARIANCE FOR RECORDS OF CLEAN WOOL WEIGHT (X_1) AND CRIMPS PER INCH (X_2) TAKEN FROM 62 EWES IN 5 YEARS

Source of variation	Degrees of freedom	Mean square (X_1)	Covariance (X_1X_2)	Mean square (X_2)	Components		
					X_1	X_1X_2	X_2
Between years	4	18.201	−12.274	10.957	.....	.....	.....
Between ewes	61	3.140	−3.513	16.304	0.5617	−.6845	2.8339
Years x ewes	244	0.332	−.090	2.134	(S_{11})	(S_{12})	(S_{22})

Records of clean wool weight were first corrected to a constant growth period of 365 days. From the records at first shearing values of $P_{11}=0.7777$, $P_{12}=-.7863$ and $P_{22}=3.7438$ were obtained. Estimates of S_{ij} were made from analyses of variance and covariance on the records for five years. The results are summarized in table 2.

Having obtained the estimates of P_{ij} and S_{ij}, the next step is to find suitable economic weights for X_1 and X_2. Dunlop and Young (1960) estimated the economic weight for crimp to be approximately 25 units if the economic weight of clean wool is to be taken as 100 units. Using these estimates the k_i values can be calculated as:

$$\begin{bmatrix} k_1 \\ k_2 \end{bmatrix} = \begin{bmatrix} 0.7777 & -0.7863 \\ -0.7863 & 3.7438 \end{bmatrix}^{-1} \begin{bmatrix} 0.5617 & -0.6845 \\ -0.6845 & 2.8339 \end{bmatrix} \begin{bmatrix} 100 \\ 25 \end{bmatrix}$$

and we have $k_1=64.6$ and $k_2=14.2$. The performance index is thus:

$$W=64.6\,x_1+14.2\,x_2 \qquad (15)$$

In actual application (15) may be written as:

$$W=4.5\,x_1+x_2$$

since only the relative values of index scores for individual animals are of interest.

The expected phenotypic gains, for 1 standard deviation of selection differential, when (15) is used were calculated and are shown under "Case 1" in table 3.

In the calculations of the accompanying increase in genetic values, the heritability estimate for both clean wool weight and crimp was taken to be 0.4 (Tallis, 1959; Young *et al.*, 1960) and the genetic correlation between them was taken to be −.6 (Tallis, 1959). From these estimates together with the estimates of P_{ij} used previously, it is estimated that $G_{11}=0.3111$, $G_{12}=-.4095$ and $G_{22}=1.4975$. The resulting estimates of genetic gains are shown in table 3 (Case 1). It can be seen that, when the performance index (15) is used, the selected sheep may be expected to show a substantial phenotypic increase in economic value but a decrease in crimp number. The accompanying genetic changes are about half the value of the phenotypic changes.

Using the same estimates of a_i, P_{ij} and G_{ij} a selection index was calculated, the coefficients being $b_1=32.9$ and $b_2=6.0$. The expected genetic gains and their accompanying phenotypic gains are also shown in table 3 (Case 1). The gains from the two indices are similar, but this is not surprising in view of the fact that the correlation between them is 0.997 (Equation 6). This high correlation means that the majority of animals selected by one index will also be selected by the other.

TABLE 3. EXPECTED PHENOTYPIC AND GENETIC GAINS BY THE APPLICATION OF DIFFERENT INDICES IN TWO SITUATIONS [a]

Type of gain	Trait	Case 1		Case 2	
		With performance index	With selection index	With performance index	With selection index
Phenotypic	Total, (economic units)	50.6	50.3	50.6	42.1
	Wool weight (lb.)	0.525	0.557	0.525	0.234
	Crimps per in. (number)	−.079	−.214	−.079	0.747
Genetic	Total, (economic units)	25.7	25.8	35.7	42.8
	Wool weight (lb.)	0.282	0.301	0.220	0.209
	Crimps per in. (number)	−.103	−.174	0.548	0.878

[a] Figures in Cases 1 and 2 were computed with two different sets of genetic parameters.

Consider now an hypothetical case where P_{ij} and S_{ij} have the same values as in Case 1, but the heritability estimates for X_1 and X_2 are 0.2 and 0.4 respectively and the genetic correlation between them is 0.2. Then G_{11}= 0.15, G_{12}=0.10 and G_{22}=1.50. The k_i values are the same as in Case 1, but now b_1=44.8 and b_2=22.1. The expected gains from both indices are shown in table 3 (Case 2).

The correlation between the two indices is 0.833 for Case 2 which is lower than for Case 1. The expected gains from the use of the two indices this time differ markedly.

Discussion

It is reasonable to assume that the permanent differences among animals are partly caused by the effects of early environment, which persist throughout the lives of animals. There is no justification, however, in assuming that the values of S_{ii} and S_{ij} will not vary with the age of the animals. The S_{ii} and S_{ij} estimated from the first two years' records, for example, may differ from the values estimated from records covering four years or more. Since the aim of using a performance index is to select animals for lifetime production, it is suggested that, for higher efficiency, S_{ij} should be estimated from records at as many ages as possible.

From the numerical examples summarized in table 3, it is clear that in some situations the use of either kind of index will lead to similar phenotypic and genetic gains in economic value. It is interesting to note that although gains in values are almost identical, changes in individual traits are not necessarily similar. For example, in Case 1, the use of a selection index will lead to a slightly greater gain in wool weight and a more appreciable decrease in crimp than when a performance index is used. In other situations, such as the hypothetical Case 2, the application of different kinds of indices will lead to quite different expected gains in values as well as in individual traits, and one index may be superior to the other. The suitability of different kinds of indices would, of course, depend on the relative importance of genetic and phenotypic gains to particular breeders of different livestock.

It is of interest to point out that the method of independent culling levels may also be used in the selection of animals for lifetime production. Formulae developed by Hazel and Lush (1942) and Young and Weiler (1960) can readily be adapted for this purpose by substituting the parameters S_{ii} and S_{ij} for G_{ii} and G_{ij}.

Summary

The theory of constructing a performance index which may be used in the selection of animals for phenotypic gains is presented. This index is compared with the genetic selection index and numerical examples are used to illustrate how the use of each index is likely to affect genetic and phenotypic gains.

Literature Cited

Dunlop, A. A. and S. S. Y. Young. 1960. Selection of Merino sheep: An analysis of the relative economic weights applicable to some wool traits. Empire J. Exp. Agr. 28:201.

Hazel, L. N. 1943. The genetic basis for constructing selection index. Genetics 28:476.

Hazel, L. N. and J. L. Lush. 1942. The efficiency of three methods of selection. J. Heredity 33:393.

Lush, J. L. 1945. Animal Breeding Plans. Collegiate Press, Ames, Iowa.

Smith, H. Fairfield. 1936. A discriminant function for plant selection. Ann. Eug. 7:240.

Tallis, G. M. 1959. Sampling errors of genetic correlation coefficients calculated from analyses of variance and covariance. Australian J. Stat. 1:35.

Turner, Helen Newton. 1958. Relationships among clean wool weight and its components. I. Changes in clean wool weight related to changes in the components. Australian J. Agr. Res. 9:521.

Young, S. S. Y., Helen Newton Turner and C. H. S. Dolling. 1960. Comparison of estimates of repeatability and heritability for some production traits in Merino rams and ewes. II. Heritability. Australian J. Agr. Res. 11:604.

Young, S. S. Y. and H. Weiler. 1960. Selection for two correlated traits by independent culling levels. J. Genetics (in press).

PHOSPHORUS REQUIREMENTS OF GROWING RABBITS

L. G. MATHIEU AND S. E. SMITH

Cornell University, Ithaca, New York

A REVIEW of the literature reveals little quantitative or even qualitative information on the phosphorus requirements of rabbits. Heinemann and coworkers (1957) observed a significantly retarded growth rate, impaired breeding efficiency, fragile bones and abnormal ossification in rabbits fed a low-phosphorus diet (0.12%). Matrone *et al.* (1954) showed that rabbits fed a ration containing 0.11% phosphorus made more rapid gains, had higher serum inorganic phosphorus levels and stronger bones than rabbits fed a similar diet containing 0.08% phosphorus.

The work reported below was designed to determine the phosphorus requirements of growing rabbits of a commercially important breed.

Experimental Procedures

A total of 104 New Zealand White rabbits was used in these studies. The ingredients of the basal, low-phosphorus diet (table 1) were mixed in a large rotatory mixer and compressed into ⅛ × ½ in. pellets.

TABLE 1. COMPOSITION OF BASAL DIET

Ingredient	Percent
Prairie hay (low in phosphorus)	40
Beet pulp	20
Blood fibrin	13
Cerelose	13
Molasses	10
Corn oil	3
Iodized salt	1
Vitamin A and D oil [a]	

[a] To supply 2250 I.U. of vitamin A activity and 300 I.U. of vitamin D per pound of feed.

Rabbits were purchased from a commercial breeder at 5 to 6 weeks of age. On arrival they were fed a ration of good quality alfalfa hay and over a period of approximately 7 days were gradually shifted onto the pelleted experimental diets.

The basal diet, analyzed according to the method of Koenig and Johnson (1942), contained 0.07% phosphorus. Desired phosphorus levels were obtained by adding dicalcium phosphate (C.P.) to the basal diet.

Experiment 1 consisted of three treatments (phosphorus levels) and lasted 45 days. Thirty-two female rabbits were divided at random into three treatment groups of 12, 10 and 10 each and fed respectively a phosphorus level of 0.07%, 0.14% or 0.28%. Experiment 2 consisted of five treatments, fed for 52 days. Thirty-two rabbits of mixed sexes were randomized among five treatment groups such that four females and four males were fed a diet containing 0.07%, 0.17%, 0.22%, 0.28% or 0.32% phosphorus.

The rabbits were housed individually in metal cages equipped with a wire mesh bottom and were fed the test diet and water *ad libitum*. Weight gains were recorded at weekly intervals. Blood was sampled by heart puncture, at the beginning, in the middle and at the end of the experiments. Serum inorganic phosphorus levels were determined by the molybdivanadate method of Simonsen *et al.* (1946) and serum alkaline phosphatase activity was calculated by the Bodansky (1933) method adapted to the use of the molybdivanadate method for measuring the phosphorus released. In each experiment four individuals of each treatment group were housed in metabolism cages and their total feed intake and feces and urine excretion measured. Feces and urine samples were subsequently analyzed for their phosphorus content, and the total phosphorus retention over a period of 40 days was determined.

At the end of the test periods, the rabbits were killed and the left femur removed and dissected free of soft tissues. The moisture, ether-extractable material and ash content of the left femur were determined (A.O.A.C., 1955). The phosphorus content of the bone ash was determined, following the method of Koenig and Johnson (1942). Density of the dry, paraffin-coated femur was determined using the water displacement principle. Tests of breaking strength were conducted by suspending, at the center of the supported bone, a load increased to the point of fracture; the weight of the load was recorded as the breaking strength.

The data collected for each criterion were

analyzed statistically by analysis of variance and treatment means were subjected to the multiple range test of Duncan (1955).

Results

Growth and feed intake of rabbits fed the semi-purified basal ration supplemented with an adequate amount of phosphorus compared favorably with the growth of rabbits fed natural rations (N.R.C., 1954). This indicates that the basal ration was nutritionally adequate except for phosphorus. Average responses of rabbits fed different phosphorus levels are presented in table 2 for Experiment 1 and in table 3 for Experiment 2.

Figure 1 presents the cumulative body weight gains of rabbits fed the different levels of phosphorus in Experiment 1, and figure 2 shows the effect of time on the serum inorganic phosphorus level of rabbits in Experiment 2.

The data obtained for the phosphorus balance studies in Experiments 1 and 2 are presented in table 4, together with the weight of the moisture-free, ether-extracted femur. It will be seen that there was a high correlation (0.90) between the amount of phosphorus retained and the weight of the femur.

Raising the levels of phosphorus intake above 0.22% of the ration did not increase significantly the amount of phosphorus retained in the body over a period of 40 days.

From the records of feed consumption and body weight gains of rabbits kept in metabolism cages it was possible to calculate the efficiency of feed conversion. These data were reduced for interpretation by covariance analysis, holding feed intake constant. On this basis there was no significant difference in the rate of feed conversion among treatment groups. From this we can draw the conclusion that observed differences in body weight gains were due primarily to differences in feed intake rather than the rate of feed conversion.

There was no indication of a sex difference in the phosphorus requirement, although the females grew at a slightly higher rate than the males in each group.

TABLE 2. AVERAGE RESPONSES OF RABBITS FED DIFFERENT LEVELS OF PHOSPHORUS. —EXPERIMENT 1

Criterion	Phosphorus level, %[a]		
	0.07	0.14	0.28
Total gain, gm.	657	981	1120**
Blood P, final, mg. %	5.8	6.9	8.4
Serum phosphatase activity final, Bodansky U.	7.2	6.3	4.9
Moisture in femur, %	44.7	35.7	33.5**
Fat in femur, %	16.3	12.3	11.3*
Ash in femur, %	50.8	57.8	59.9**
Phosphorus in femur, %	8.7	9.7	9.8**
Weight of dry, fat-free femur, gm.	2.61	3.99	4.80**
Density of femur	0.742	0.937	1.024*
Breaking strength of femur, lb.	11.4	22.8	28.4**

[a] Mean values not underlined by the same line are significantly different.
* Differences significant at the 5% level.
** Differences significant at the 1% level.

From the combined observations in Experiment 1 it is clearly evident that a phos-

TABLE 3. AVERAGE RESPONSES OF RABBITS IN EXPERIMENT 2

Criterion	Phosphorus level, %[a]				
	0.07	0.17	0.22	0.28	0.32
Total gain, gm.	742	1138	1170	1066	1147**
Blood P., final, mg. %	5.16	7.05	7.21	7.61	7.57**
Serum phosphatase activity final, Bodansky U.	8.4	5.8	5.6	5.1	5.1*
Moisture in femur, %	39.0	30.8	31.6	31.8	30.8**
Fat in femur, %	15.3	13.7	11.6	10.6	11.7*
Ash in femur, %	49.5	55.6	57.1	58.3	58.0**
Phosphorus in femur, %	9.3	9.6	9.7	9.7	9.8
Weight of dry, fat-free femur, gm.	3.28	4.70	5.02	5.13	5.03**
Density of femur	0.726	0.902	0.943	1.001	1.007**
Breaking strength of femur, lb.	14.0	22.3	25.3	25.5	24.5**

[a] Mean values not underlined by the same line are significantly different.
* Differences significant at the 5% level.
** Differences significant at the 1% level.

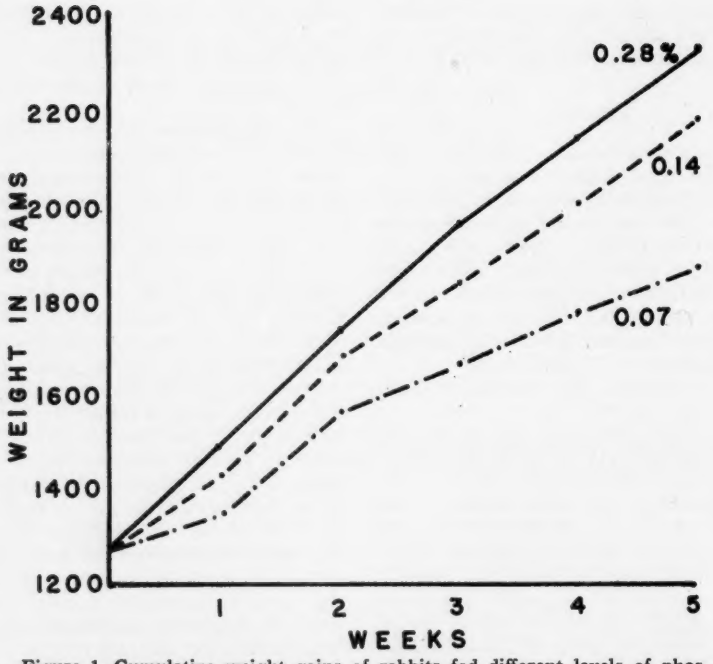


Figure 1. Cumulative weight gains of rabbits fed different levels of phosphorus. The values on the right side of the graph represent percent phosphorus in the air-dried ration. Experiment 1.

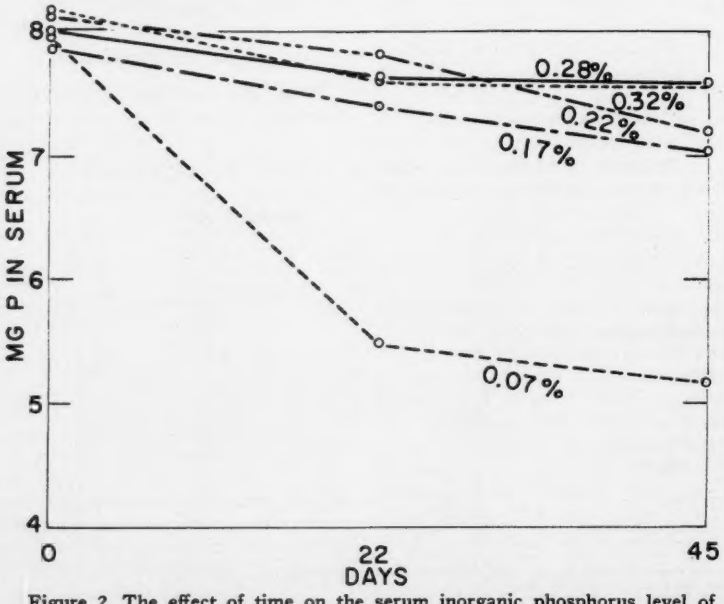


Figure 2. The effect of time on the serum inorganic phosphorus level of rabbits fed different levels of phosphorus. Experiment 2.

TABLE 4. DATA OF THE PHOSPHORUS BALANCE STUDY EXPERIMENTS 1 AND 2 [a]

Criterion	Experiment 1 Phosphorus level, % 0.07	0.14	0.28
Experiment 1			
Av. phosphorus intake, gm.	2.142	4.844	10.724
Av. phosphorus excretion, gm.	0.785	1.075	6.036
Av.phosphorus retention, gm.	1.357	3.769	4.688**
Weight of femur, gm.	2.61	3.99	4.80**
	Experiment 2 Phosphorus level, % 0.22	0.28	0.32
Experiment 2			
Av. phosphorus intake, gm.	10.925	13.998	16.260
Av. phosphorus excretion, gm.	5.518	8.207	10.795
Av. phosphorus retention, gm.	5.407	5.791	5.465
Weight of femur, gm.	4.67	5.07	5.05

[a] Data are average of 4 individuals per group.
** Differences significant at the 1% level.

phorus level of 0.14% is below the minimum requirement. In Experiment 2 there was no significant difference among treatment groups of rabbits fed 0.22% or higher levels of phosphorus for any of the criteria studied. In comparing the responses of rabbits fed either 0.17 or 0.22% of phosphorus, it will be noted that while differences are slight, they favor in every case, except serum phosphatase activity, those fed the higher level. From this we conclude that a phosphorus level near 0.22% approximates the minimum requirement of growing rabbits.

It will be recognized that the phosphorus requirement here established is in terms of the phosphorus compounds present in the diet, 68% of which was from dicalcium phosphate and the remainder from organically-bound or so-called phytin phosphorus. The phosphorus of dicalcium phosphate has been shown to be highly available for all animals so far studied, although specific studies with rabbits have not been published. The phosphorus of organically-bound compounds differs in availability with species being highly available in ruminants and poorly available in non-ruminants. In the absence of published data, we can only assume that rabbits fall in the latter category.

Summary

A total of 104 weanling New Zealand White rabbits were used in a study to determine the minimum phosphorus requirement. A pelleted semi-purified basal diet containing 0.07% phosphorus was supplemented with dicalcium phosphate to provide phosphorus levels of 0.14 and 0.28% in Experiment 1 and 0.17, 0.22, 0.28 and 0.32% in Experiment 2. Several response criteria were used to assess the adequacy of phosphorus levels: body weight gains, blood phosphorus levels, alkaline phosphatase activity of the blood, bone weight, bone ash content, bone density and breaking strength and others.

From the combined data of both experiments, it is evident that a dietary level of 0.22% approximates the minimum requirement for phosphorus.

Literature Cited

A.O.A.C. 1955. Official and tentative methods of analysis. Association of Official Agricultural Chemists, Washington, D.C.

Bodansky, A. 1933. Phosphatase studies. Determination of serum phosphatase. Factors influencing the accuracy of the determination. J. Biol. Chem. 101:93.

Duncan, D. B. 1955. Multiple range test and multiple F tests. Biometrics 2:1.

Heinemann, W. W., M. E. Ensminger, W. E. Ham and J. E. Oldfield. 1957. The effects of phosphate fertilization of alfalfa on growth, reproduction and body composition of domestic rabbits. J. Animal Sci. 16:467.

Koenig, R. A. and C. R. Johnson. 1942. Colorimetric determinations of phosphorus in biological material. Ind. Eng. Chem. Anal. Ed. 14:155.

Matrone, G., F. H. Smith, V. B. Weldon, W. W. Woodhouse, W. J. Peterson and K. C. Beeson. 1954. Effects of phosphate fertilization on the nutritive value of soybean forage for sheep and rabbits. U.S.D.A. Tech. Bul. No. 1086.

N.R.C. 1954. Nutrient Requirements of Domestic Animals. IX. Nutrient Requirements for Rabbits. National Research Council, Washington, D.C.

Simonsen, D. G., M. Wertman, L. M. Westover and J. W. Mehl. 1946. The determination of serum phosphate by the molybdivanadate method. J. Biol. Chem. 166:747.

COMPARATIVE UTILIZATION OF DIETARY CALCIUM AND STRONTIUM-90 BY PIGS AND SHEEP

D. E. Hogue, W. G. Pond, C. L. Comar, L. T. Alexander and E. P. Hardy [1]

Cornell University, Ithaca, New York, U. S. Department of Agriculture [2] *and U. S. Atomic Energy Commission* [3]

CONTAMINATION of the biosphere with strontium-90 from nuclear debris has required that an understanding be attained of the movement of this radionuclide through the food chain. The advantages and concepts in considering the comparative behavior of calcium and strontium have been established, and the magnitude of the preferential utilization of calcium over strontium in many species has been determined (Comar *et al.*, 1955; Comar *et al.*, 1956; Wasserman *et al.*, 1958, Comar *et al.*, 1957; U. N. Sci. Comm., 1958). In general, it has been observed that dietary strontium is retained in the body only about one-fourth as effectively as is calcium. These data have usually been obtained by procedures based on comparison in precursors (diets) and in tissues, of natural strontium-calcium ratios or of added radionuclides of the two elements. As discussed by Comar *et al.* (1957), these methods all have uncertainties. The absolute procedure is to measure the total strontium and calcium consumed by an animal or individual during the entire lifetime and then to measure the strontium and calcium in the total bone; for large animals and man it has been difficult, if not impossible, to obtain such data.

The present study was undertaken in order to: (a) utilize a direct approach in the estimation of the comparative behavior of calcium and strontium, (b) obtain data on fallout Sr^{90} as it occurred in a usual ration, (c) obtain data on pigs and sheep, two species for which there has been little or no information available, (d) provide values for Sr^{90} and calcium utilization from feed during the period and for the conditions of the experiment.

Experimental

General Procedure. Six similar animals of each species were used, and at the start of the experimental period, the controls (three pigs and three lambs) were killed for analysis. The remaining animals were fed for 3 to 5 months and then killed for analysis. The calcium and Sr^{90} content of the control animals was used to calculate that of the experimental animals at the start of the feeding trial; these values subtracted from the final contents of calcium and Sr^{90} gave the body gain in these two substances. From analysis of representative aliquots of the feed consumed, it was then possible to calculate the comparative utilization of calcium and Sr^{90}.

Animals and Feeds. Six pigs from a litter of nine crossbred Yorkshire x Chester White swine from the Cornell University swine herd were used in this study. These pigs were farrowed on concrete May 19, 1958, and remained in the same concrete pen during the suckling period. The sow was fed a conventional lactation ration during the 8-week nursing period. After weaning, on July 14, 1958, the litter remained on concrete until the feeding period began. During this time the litter was self-fed a ration made up of feedstuffs purchased on the open market with no knowledge of source.

On August 6, 1958, the six experimental animals were selected at random from the litter of nine pigs. Three of these pigs were randomly selected as the negative controls and were slaughtered with the bones being removed from the carcass (minus head) for analysis. The three remaining pigs were fed the ration shown in table 1; they were kept in a concrete pen, fed *ad libitum* from a self-feeder during the entire feeding period, with tap water supplied *ad libitum*. The pigs were fed from August 13, 1958, until they were slaughtered on December 30, 1958, 139 days, with the bones being removed as for the controls. Samples of the individual feed-

[1] The authors acknowledge the help of G. H. Wellington and J. R. Stouffer in regard to slaughter of animals, E. J. Thacker and K. E. Beeson for assistance in handling of whole animal carcasses, R. Dever for ashing of the samples, and G. Hamada who performed the analyses.

[2] Soil Conservation Service, Plant Industry Station, Beltsville, Maryland.

[3] Analytical Division, Health and Safety Lab., N. Y. Operations Office.

TABLE 1. COMPOSITION OF RATION

Ration[a]	Percent
Corn (No. 2 yellow)	68.0
Soybean meal (44% solvent)	6.0
Antibiotic supplement[b]	0.5
Trace mineralized salt	0.5
Ground mixed hay (first cutting from Cornell, 1958)	25.0
	100.0

[a] Supplemented with 400 I.U. and 90 I.U. of Vitamin A and D, and 1, 2, 4.5, 5 and 0.03 mg. of riboflavin, pantothenic acid, niacin, choline chloride, and folic acid, respectively, per pound of feed. Ration calculated to contain 12 percent protein.
[b] Aurofac 2A furnished by American Cyanamid Co., Pearl River, N. Y. This amount supplies 18 mg. of aureomycin per pound of feed plus appreciable quantities of vitamin B_{12}.

stuffs and of the mixed ration were also saved for calcium and strontium determination. The body weights of all six pigs when the trial started and the final weights of the three test pigs are shown in table 2.

Six lightweight native feeder lambs (Hampshire x Whiteface) from the grade flock at Cornell University were selected on the basis of weight for the trial. They had been on pasture without supplemental grain feeding for approximately 60 days. From the six experimental lambs, three were randomly selected as negative controls and were slaughtered on August 13, 1958. All carcasses were boned out (except for the head) and the bones prepared for calcium and strontium-90 determination. The three remaining lambs were group fed for 83 days (August 20 to November 12, 1958) at which time they were slaughtered and treated similarly to the negative control lambs. Hay was full fed with weighbacks recorded and sampled. Concentrates were fed in limited amounts and tap water was available at all times. The feeds were the same as for the swine. The body weights and gains are summarized in table 3.

Analytical Methods. The analytical procedures were those described by Whitney (1957). As a measure of the analytical reproducibility, the average percent standard deviation between duplicates was 3.9% for the bones and 10% for the diet samples when the results are expressed as micromicrocuries ($\mu\mu$c) Sr^{90}/gm. Ca.

The whole skeleton, minus the head, of each animal was used in these experiments. The bones were dried at 105° C. and then broken into suitable small pieces that were placed in porcelain evaporating dishes. The dishes were then placed in an electric muffle furnace regulated at 650° C. and ashed to a white residue. (This takes 4 to 5 hours with free air circulation.) In some cases, the temperature was raised to 800° C. for one or two hours to burn the more persistent carbon. The bone ash was ground to a fine powder with a mortar and pestle. The ash from each skeleton was combined, thoroughly mixed, and aliquoted for analysis.

Results

Pigs. Table 4 presents the calcium and Sr^{90} values on the feed consumed by the pigs. It is of interest to note that the hay contributed about 78% of the calcium and about 90% of the Sr^{90}; this was a result of the relative high value of 89.7 $\mu\mu$c Sr^{90}/gm. Ca for the hay, which was from the 1958 crop year.

Table 5 gives values for the individual control pigs. It is of interest to note the good agreement in calcium values expressed as percentage of body weight and in Sr^{90} expressed as micromicrocuries per gram of calcium. These values were used in estimating the levels in the experimental pigs at the start of the feeding trial; the agreement obtained would indicate that no large errors could have been introduced by this type of calculation.

Table 6 summarizes the data for the experimental pigs and includes the values calculated from the control series to permit estimation of the net gain of stable calcium and Sr^{90}. The comparative behavior is expressed in terms of the strontium-calcium observed ratio (OR) as defined by Comar *et al.* (1956).

$$OR_{body/diet} = \frac{Sr/Ca \text{ of Body}}{Sr/Ca \text{ of Diet}} \qquad (1)$$

TABLE 2. BODY WEIGHT DATA FOR PIGS

	Controls			Experimental		
Pig no.	1	2	3	4	5	6
Initial body wt., kg.	15.5	10.0	21.8	23.6	24.0	20.0
Final body wt., kg.	....	....	....	104.5	95.9	91.8
Gain, kg.	....	....	....	80.9	71.9	71.8
Av. daily gain, kg.	....	....	....	0.58	0.52	0.52

TABLE 3. BODY WEIGHT DATA FOR SHEEP

	Controls			Experimental		
Sheep no.	1	2	3	4	5	6
Initial body wt., kg.	21.8	19.5	18.1	22.3	21.4	20.0
Final body wt., kg.	....	....	....	37.3	36.8	32.7
Gain, kg.	....	....	....	15.0	15.4	12.7
Av. daily gain, kg.	....	....	....	0.18	0.19	0.15

TABLE 4. DATA ON FEED CONSUMED BY EXPERIMENTAL PIGS

Ration	Total	Calcium	Sr^{90}	Sr^{90}/Ca
	kg.	gm.	$\mu\mu c$	$\mu\mu c$/gm.
Corn	590.0	172	3870	22.3
Soybean meal	52.0	153	1017	6.7
Hay	216.9	1175	105363	89.7
Antibiotic supplement	4.3	....	.....	....
Trace mineralized salt	4.3	....	.....	....
Total ration	867.5	1500	110250	73.5

TABLE 5. DATA ON CONTROL PIGS KILLED AT START OF EXPERIMENT

Pig no.	1	2	3	Average
Body wt., kg.	15.5	10.0	21.8	....
Calcium, gm.	110	68.4	156	....
Calcium, % of body wt.	0.71	0.68	0.71	0.70
Sr-90, $\mu\mu c$	363	284	588	....
$\mu\mu c$ Sr^{90}/gm. Ca	3.31	4.14	3.78	3.74

TABLE 6. DATA ON EXPERIMENTAL PIGS

Pig no.	4	5	6	Average
Initial calcium, gm.[a]	166	169	141	....
Final calcium, gm.	376	425	396	....
Initial Sr^{90}, $\mu\mu c$[b]	621	632	527	....
Final Sr^{90}, $\mu\mu c$	3504	3894	3808	....
Final $\mu\mu c$ Sr^{90}/gm. Ca	9.32	9.16	9.56	9.35
Calcium gain, gm.	210	256	255	....
Sr^{90} gain, $\mu\mu c$	2883	3262	3281	....
$\mu\mu c$ Sr^{90}/gm. Ca in gain	13.7	12.7	12.9	....
OR body/diet[c]	0.19	0.19	0.17	0.18
Calcium utilization, %	....	....	....	48.1
Sr^{90} utilization, %	....	....	....	8.55

[a] Calculated by 0.70% times body weight (See table 5).
[b] Calculated by 3.74 times body calcium (See table 5).
[c] Calculated by $\mu\mu c$ Sr^{90}/gm. Ca in gain divided by 73.5 which is $\mu\mu c$ Sr^{90}/gm. Ca in total ration (See table 4).

TABLE 7. DATA ON FEED CONSUMED BY EXPERIMENTAL SHEEP

Ration	Total	Calcium	Sr^{90}	Sr^{90}/Ca
	kg.	gm.	$\mu\mu c$	$\mu\mu c$/gm. Ca
Corn	125	36.6	824	22.3
Soybean meal	10.3	30.3	202	6.7
Hay offered	220	1194	107086	89.7
Weighback	50.7	449	31390	69.8
Total ration	305	812	75696	94.5

TABLE 8. DATA ON CONTROL SHEEP KILLED AT START OF EXPERIMENT

Sheep no.	1	2	3	Average
Body wt. kg.	21.8	19.5	18.1	....
Calcium, gm.	146	132	116	....
Calcium, % of body wt	0.67	0.68	0.64	0.66
Sr-90, $\mu\mu c$	4342	4605	3048	....
$\mu\mu c$ Sr^{90}/gm. Ca	29.7	34.8	26.3	30.3

It is noted that an average $OR_{body/diet}$ of 0.18 is obtained which is in general agreement with that expected from previous studies with other species.

It may also be noted that the calcium utilization was about 48% and the Sr^{90} about 8.6%.

Sheep. The data for sheep are presented as for the pigs in tables 7, 8 and 9. From table 7 it can be calculated that the hay furnished about 92% of the calcium and about 99% of the Sr^{90}. Table 8 shows that the control sheep had an average calcium content of 0.66% of body weight with good agreement among individuals. The value of 30.3 $\mu\mu c$ Sr^{90}/gm. Ca was significantly higher than for the pigs, and the reason for this will be discussed later. Table 9 shows an average $OR_{body/diet}$ of 0.21 with 29.6% calcium utilization and 6.3% Sr^{90} utilization.

Discussion

Assumptions and possible sources of error in this study are as follows: (a) the heads were not included in the analysis of control or experimental animals, (b) the calcium and Sr^{90} in the different components of the ration may have been utilized differentially, (c) there was probably some replacement of existing calcium and Sr^{90} stored during the feeding period and (d) calcium and Sr^{90} intake with drinking water was not included.

TABLE 9. DATA ON EXPERIMENTAL SHEEP

Sheep no.	4	5	6	Average
Initial calcium gm.[a]	147	141	133	....
Final calcium	220	231	210	....
Initial Sr^{90} $\mu\mu c$[b]	4454	4272	4030	....
Final Sr^{90}	5908	6274	5351	....
Final $\mu\mu c$ Sr^{90}/gm. Ca	26.8	27.2	25.5	26.5
Calcium gain gm.	73	90	77	....
Sr-90 gain $\mu\mu c$	1454	2002	1321	....
$\mu\mu c$ Sr^{90}/gm. Ca in gain	19.9	22.2	17.2	....
OR body/diet[c]	0.21	0.23	0.18	0.21
Calcium utilization %	....	....	....	29.6
Sr-90 utilization	....	....	....	6.3

[a] Calculated by 0.66% times body weight (See table 8).
[b] Calculated by 30.3 times body calcium (See table 8).
[c] Calculated by $\mu\mu c$ Sr^{90}/gm. Ca in gain divided by 94.5 which is $\mu\mu c$ Sr^{90}/gm. Ca in total ration (See table 7).

It is considered that no large errors were introduced and this is confirmed by the fact that the OR values of 0.18 and 0.21 for the pigs and sheep, respectively, are in agreement with values based on other methods having different uncertainties: e.g. cow —0.21, goat —0.23, (Comar and Wasserman, 1960); sheep —0.24, (Jones and Mackie, 1959).

It was of interest to note that the pigs started with 3.7 $\mu\mu$c Sr^{90}/gm. Ca and ended with a value of 9.4; on the other hand, the sheep started with a value of about 30 and ended with a slight fall, if any, to about 27. The initial high value for the sheep is accounted for by the fact that most of their bone had been formed on pasture which must have had a Sr^{90}/Ca ratio about the same as did the experimental ration, whereas the pigs' bone had been formed mainly from milk which would have about one-eighth the Sr^{90}/Ca ratio of current pasture.

Summary

The comparative utilization of dietary calcium and of Sr^{90} was determined in pigs and sheep under typical management conditions by balance feeding trials, radioassay for Sr^{90} present in feedstuffs in 1958, and chemical analysis for calcium.

A ration consisting of hay from crop year 1958, soybean meal and corn ranged from 74 to 93 $\mu\mu$c Sr^{90}/gm. Ca. The hay contributed about 90% of the Sr^{90} intake of the animals.

The pigs started with a body burden of 3.7 $\mu\mu$c Sr^{90}/gm. Ca and finished with 9.4; comparative values for the sheep were 30 and 27. For the pigs the comparative utilization of calcium and Sr^{90} was 48 and 8.6% respectively; values for the sheep were 30 and 6.3%.

In agreement with values for other species, the pigs and sheep utilized Sr^{90} about 0.2 as effectively as calcium.

Literature Cited

Comar, C. L., R. S. Russell and R. H. Wasserman. 1957. Strontium-calcium movement from soil to man. Science. 126:485.

Comar, C. L. and R. H. Wasserman. 1960. Radioisotope absorption and methods of elimination: Differential behavior of substances in metabolic pathways. In Radioisotopes in the Biosphere, p. 526. Center for Continuation Study, University of Minnesota, Minneapolis.

Comar, C. L., R. H. Wasserman and M. M. Nold. 1956. Strontium-calcium discrimination factors in the rat. Proc. Soc. Exp. Biol. Med. 92:859.

Comar, C. L., I. B. Whitney and F. W. Lengemann. 1955. Comparative utilization of dietary Sr-90 and calcium by developing rat fetus and growing rat. Proc. Soc. Exp. Biol. Med. 88:232.

Jones, H. G. and W. S. Mackie. 1959. The metabolism in sheep of the alkaline earth products of fission. British J. Nutr. 13:355.

U.N. Sci. Comm. on Effects of Atomic Radiation, Rep., 1958. Supp. No. 17 (A/3838), N. Y.

Wasserman, R. H., F. W. Lengemann and C. L. Comar. 1958. Comparative metabolism of calcium and strontium in lactation. J. Dairy Sci. 41:812.

Whitney, I. B. ed., 1957. HASL Manual of Standard Procedures. USAEC, New York Operations, Report No. 4700.

TOLERANCE OF GROWING CATTLE FOR DRINKING WATER CONTAINING SODIUM CHLORIDE [1]

H. J. Weeth and L. H. Haverland [2]

University of Nevada, Reno

IT has been reported that growing heifers could consume, during winter, water containing 1% NaCl without deleterious effects (Weeth *et al.*, 1960). Water containing 2% NaCl was toxic, causing severe anorexia, weight loss and anhydremia. Hypernatremia of greater magnitude than that found in acutely salt-loaded dogs (Winkler *et al.*, 1944) was occasionally observed in the heifers drinking 2% salt water (Weeth *et al.*, 1960). From this experiment, it appears that the tolerance level of NaCl in the drinking water of growing cattle lies between 1 and 2%. This report concerns attempts to define more closely NaCl concentrations which are safely tolerated. Reported are two experiments, one conducted during winter and one during summer.

Methods

Six Hereford heifers were used in a change-over design in each of the two experiments. There were three treatments and three periods of 30 days, each period being divided into either two (winter experiment) or three (summer experiment) phases. Animals were penned separately. Feed and water consumption were recorded. The feed was chopped alfalfa hay, *ad libitum*. The NaCl was added to tap water containing about 100 ppm of dissolved solids.

Winter Experiment. Heifers were about 9 months old and averaged 411 lb. Percentages of salt added to the drinking water were 1.25, 1.50 and 1.75. Every 15 days, the heifers were weighed and a sample of jugular blood was taken. Serum was separated from a portion of the blood. The rest was drawn into heparinized tubes (0.2 mg. sodium heparinate per ml. blood). Rectal temperatures and pulse and respiration rates were also recorded at 15 days.

Methods used for analyses of blood, plasma or serum were: (1) hematocrits by capillary tube centrifugation, (2) serum sodium and potassium by flame photometry of protein-free-filtrate, (3) total plasma protein by biuret (Reiner, 1953), (4) serum glutamic-oxalacetic transaminase (SGO-T) according to Sigma (Anonymous, 1959), (5) plasma calcium by Kramer-Tisdall (Hawk *et al.*, 1947), and (6) blood urea by diacetylmonoxide method of Friedman (1953).

Average air temperatures for the three change-over periods were 41, 32 and 24° F. Total precipitation was 1.49 inches.

Summer Experiment. Heifers were about 9 months old and averaged 398 lb. Percentages of NaCl added to drinking water were 0, 1 and 1.2. Procedures used were generally the same as in the winter experiment, except observations were taken every 10 days. Respiration rate, plasma protein, plasma calcium and SGO-T were not determined. In addition, serum magnesium was determined by the fluorometric method of Schachter (1959).

Average air temperatures for the three change-over periods were 66, 71 and 62° F. There was no precipitation.

All data were subjected to analysis of variance using a mixed model (Snedecor, 1956). Percentage NaCl in the water (treatment) was considered a fixed factor. Period and days-on-treatment were considered random factors.

Results and Discussion

Winter Experiment. Heifers consuming 1.75% salt water showed the overt symptoms of dehydration previously described (Weeth *et al.*, 1960). There was some appearance of dehydration in heifers consuming 1.50% salt water. Heifers appeared normal on 1.25% salt water, although if previously dehydrated, recovery was slow.

As indicated in table 1, heifers drank less 1.75 than 1.25% NaCl water. A significant treatment x period interaction was due to

[1] Conducted in cooperation with Western Regional Research Project W-46, The Effects of Environmental Stresses on Range Cattle and Sheep Production.

[2] Department of Animal Husbandry.

TABLE 1. MEAN VALUES FROM WINTER SALT WATER EXPERIMENT

Item	% NaCl added to water		
	1.25	1.50	1.75
Water consumed daily, lb.	33	25	19**
Hay consumed daily, lb.	7.1	5.6*	3.7*
Wt. change, lb/15 days	8.3	—.1	—25.8**
Rectal temperature, ° F.	103.3	103.4	103.5
Pulse rate/min.	88	94	74
Respiration rate/min.	20	17	12**
Hematocrit, vol. %	41.3	43.7	45.4
Serum Na, mg. %	346	345	399*
Serum K, mg. %	18.7	20.3	20.3
Plasma Ca, mg. %	13.4	13.6	12.1
Plasma protein, gm. %	9.6	9.5	9.9
Blood urea, mg. %	26.7	26.6	32.4
SGO-T units	81	70	66[a]

* Differs at 5% level from 1.25% NaCl water treatment.
** Differs at 1% level from 1.25% NaCl water treatment.
[a] Does not include one heifer which died with SGO-T of 480 units.

increased consumption of 1.25 and 1.75% salt water and decreased consumption of 1.50% salt water in Period 2. Feed consumption was less in Period 1 than in Periods 2 or 3. There was a significant treatment x period interaction on feed consumption. This was the result of the large increase in hay consumption on 1.75% NaCl in Periods 2 and 3. Hay consumption on 1.25% NaCl water averaged only 1.8 lb. daily per 100 lb. body weight. In a previous winter experiment (Weeth *et al.*, 1960), growing heifers ate 2.7 lb. daily per 100 lb. while drinking 1% salt water.

Growth rate, as indicated by weight change, was lower on 1.75 than on 1.25% salt water. All animals lost weight during the first 15 days on 1.75%, but half regained some of the loss in the second 15 days. Heifers lost weight the first 15 days on 1.50% NaCl, but regained this loss during the second 15 days. The weight change and feed consumption data suggest some adaptation to the salt water. Peirce (1957b) has indicated that sheep adapt to high concentrations of NaCl in the drinking water.

There were no differences in rectal temperatures or pulse rates. Respiration rates were lower on the 1.75 than on 1.25% NaCl water. There were no significant treatment differences in hematocrits, however, the values were higher than those previously observed with heifers drinking 1% NaCl water (Weeth *et al.*, 1960).

Serum sodium was 15.3% higher on the 1.75% than on the 1.25% NaCl water treatment. There were no significant treatment differences in serum potassium or plasma calcium. A significant period x days-on-treatment interaction with plasma protein was due to consistent decreases from Periods 1 through 3 after 30 days on treatment. There was a significant interaction among main effects with blood urea. The only consistent observation ($P<0.10$) was toward increased blood urea on the 1.75% salt water.

SGO-T units showed a significant treatment x period interaction. This was caused by one heifer which, during Period 1, stopped eating and drinking after 22 days on 1.75% NaCl. On the last day of the period she was prostrate. General symptoms were those of calcium deficiency, although plasma calcium was normal. There was extreme anhydremia (hematocrit 54.0 vs. 45.4% for treatment average). Serum sodium was elevated to 694 mg. %. SGO-T was 480 units compared to 66 for other heifers on 1.75% NaCl. The heifer did not respond to forced hydration and feeding. Upon sacrifice, complete occlusion of one ureter was found. The occlusion appeared to be congenital.

Summer Experiment. In preliminary studies, heifers refused to drink 1.50% NaCl water. Therefore, 1.2% NaCl was selected as the maximum salt concentration to offer. This concentration was readily consumed. There were no outward symptoms of dehydration. In fact, heifers drinking 1 and 1.2% NaCl were usually diarrheal.

Water consumption was significantly elevated on both salt water treatments (table 2). Consumption of water containing 1.2% NaCl increased 124% from Period 2 to 3. There was a significant treatment x days-on-treatment interaction due to a large increase in consumption of 1% salt water between 20 and 30 days on treatment. Consumption of salt water was erratic. One heifer on 1.2% NaCl drank 32% of her body weight daily over the 30-day period. Feed consumption was reduced 28.2% on 1.2% salt water, but was unaffected by 1% NaCl. Consumption

TABLE 2. MEAN VALUES FROM SUMMER SALT WATER EXPERIMENT

Item	% NaCl added to water		
	0	1	1.2
Water consumed daily, lb.	58	85**	98**
Hay consumed daily, lb.	11.7	10.4	8.4**
Wt. change, lb/10 days	12	8	2
Rectal temperature, ° F.	103.8	103.5	104.1**
Pulse rate/min.	96	87	78**
Hematocrit, vol. %	37.8	37.2	38.1
Serum Na, mg. %	344	345	356**
Serum K, mg. %	18.6	22.6*	23.2*
Serum Mg, mg. %	2.2	1.6**	1.3**
Blood urea, mg. %	25.9	19.8**	18.6**

* Differs at 5% level from 0% NaCl water treatment.
** Differs at 1% level from 0% NaCl water treatment.

tended to increase with periods ($P<0.10$). There were no treatment differences in body weight changes. This is not surprising, since the heifers were not shrunk before weighing, and consumption of salt water fluctuated widely.

Rectal temperatures were increased by the 1.2% salt water treatment. This increase was most apparent after 20 and 30 days on treatment. Pulse rates were significantly reduced by 1.2% but unaffected by 1% salt water. A treatment x period interaction was apparently due to trends toward decreased pulse rates on salt water from Periods 1 through 3 while pulse rates on tap water increased.

Observations on hematocrit values do not indicate anhydremia. Contrariwise, a significant treatment x period interaction with hematocrit was due to decreased hematocrits on salt water in Period 3. In Period 3, hematocrit values on salt water were lower than those on tap water. This is consistent with increased water consumption in Period 3.

Serum sodium was unchanged on 1% NaCl, but increased 3.2% ($P<0.01$) on 1.2% salt water. Serum potassium was elevated by both salt water treatments. Serum magnesium was decreased by both salt water treatments. Serum magnesium decreased with periods on 1.2% NaCl, but not on 0 and 1% NaCl water.

Blood urea values were lower on both salt water treatments. Differences among treatments were relatively greater in Period 3, when blood urea was markedly reduced on 1.2% salt water. This was also a period of high consumption of 1.2% salt water. It has been suggested (Weeth *et al.*, 1960) that hyperposia, such as occurs with salt in the drinking water, may cause increased excretion of urea and lower blood urea. In the summer study, the correlation between water consumption and blood urea was $-.68$ ($P<0.01$). In the winter experiment, the salt water did not cause hyperposia and blood urea was unchanged.

From the two experiments reported here and from a previous report (Weeth *et al.*, 1960), it appears that growing cattle can tolerate 1% NaCl water during winter or summer. The effects of 1.2% salt water during summer are more severe than those of 1.25% NaCl during winter; and in fact, 1.2% salt water produced elevated serum sodium during summer, but 1.50% NaCl water when consumed in winter did not increase serum sodium. It would be important to observe the long-term effects of 1% salt water on growing cattle.

The symptoms of salt toxicity resemble those of simple dehydration (Knowles, 1956; Peirce, 1957a; Medway and Kare, 1959). However, when growing cattle were offered slightly hypertonic solution of NaCl (1.2%) water consumption was increased, there was no evidence of dehydration, yet growth was depressed. When salt concentration was further increased, water consumption decreased and the animals showed symptoms of dehydration.

Summary

In a winter change-over experiment, six heifers were offered drinking water containing 1.25, 1.50 and 1.75% NaCl. Experimental periods were 30 days long. A similar experiment was conducted during summer, using 0, 1 and 1.2% NaCl water.

In the winter experiment, 1.75% NaCl caused symptoms of salt toxicity such as anorexia, decreased water consumption and reduced growth. Heifers merely maintained themselves on 1.50% NaCl and growth did not appear optimal on 1.25% salt water. Consumption of water containing 1.5 and 1.75% NaCl was 24.2 and 42.4%, respectively, lower than consumption of 1.25% salt water.

Observations from the summer experiment indicate that heifers were unaffected by 1% NaCl water, but were adversely affected by 1.2%; yet, there were no symptoms of dehydration. Serum potassium and sodium were significantly increased by 1.2% salt water. Serum magnesium was decreased. Blood urea was decreased by both 1 and 1.2% NaCl. This may have been due to the increased water consumption on these treatments. There was a negative correlation ($r=-.68$) between water consumption and blood urea concentration. Water consumption was increased 46.6 and 69.0% by the addition of 1 and 1.2%, respectively, of NaCl to the drinking water.

Literature Cited

Anonymous. 1959. Serum glutamic-oxalacetic transaminase and serum glutamic-pyruvic transaminase. Sigma Tech. Bul. 505.

Friedman, H. S. 1953. Modification of the determination of urea by the diacetylmonoxide method. Anal. Chem. 25:662.

Hawk, P. B., B. L. Oser and W. H. Summerson. 1947. Practical Physiological Chemistry (12th ed.). The Blakiston Co., Philadelphia.

Knowles, H. C., Jr. 1956. Hypernatremia. Metabolism 5:508.

Medway, W., and M. R. Kare. 1959. The mechanism of toxicity associated with an excessive intake of sodium chloride. Cornell Vet. 49:241.

Peirce, A. W. 1957a. Saline content of drinking water for livestock. Vet. Rev. and Annotations 3:37.

Peirce, A. W. 1957b. Studies on salt tolerance of sheep. 1. The tolerance of sheep for sodium chloride in the drinking water. Australian J. Agr. Res. 8:711.

Reiner, M. 1953. Standard Methods of Clinical Chemistry, Vol. 1. Academic Press, New York.

Schachter, D. 1959. The fluorometric estimation of magnesium in serum and in urine. J. Lab. Clin. Med. 54:763.

Snedecor, G. W. 1956. Statistical Methods (5th Ed.). Iowa State College Press, Ames, Iowa.

Weeth, H. J., L. H. Haverland and D. W. Cassard. 1960. Consumption of sodium chloride water by heifers. J. Animal Sci. 19:845.

Winkler, A. W., J. R. Elkinton, J. Hopper, Jr. and H. E. Hoff, 1944. Experimental hypertonicity: Alteration in the distribution of body water, and the cause of death. J. Clin. Invest. 23:103.

PHOSPHORIC ACID AS A PHOSPHORUS SOURCE FOR BEEF CATTLE [1, 2]

D. Richardson, F. H. Baker,[3] E. F. Smith and R. F. Cox

Kansas Agricultural Experiment Station, Manhattan

COMMON sources of supplemental phosphorus, such as dicalcium phosphate and steamed bone meal, supply calcium to rations in which calcium may already be present in sufficient quantity. Richardson *et al.* (1955) and Menzies (1956) reported that phosphoric acid compared favorably with steamed bone meal as a source of supplemental phosphorus for heifers on dry bluestem pastures. In a phosphorus balance study with lambs, Menzies (1956) found that phosphorus from phosphoric acid was utilized very efficiently.

The present study was designed to examine further the use of phosphoric acid as a phosphorus supplement and to compare phosphoric acid with steamed bone meal in wintering and fattening rations.

Experimental Procedure

Seventy-four Hereford heifer calves from the same herd were divided into five lots on the basis of weight and type. Ten animals were placed in the control lot and 16 in each of the other lots. The average initial weight per animal was 441 lb.

The control ration consisted of ¾ lb. soybean meal, ½ lb. dehydrated alfalfa meal, 2 lb. dehydrated ammoniated hydrol product (Dex-Mo-Lass, made with ammoniated hydrol), and all of a corncob-blackstrap molasses mixture that the animals would clean up each day. The corncob-molasses mixture contained approximately 22% molasses for the first 84 days, then 40% molasses. When the molasses concentration was increased, 1.5% each of ground limestone and salt was added to retard "setting up" of the mixture. The limestone was decreased to .75% after about 30 days. The soybean meal and dehydrated alfalfa meal were made into pellets containing approximately 10% molasses. The supplementary phosphorus was included in the pellets as either phosphoric acid or steamed bone meal. Salt alone and a mixture of ground limestone and salt were available to all animals free choice.

The control ration supplied 6 gm. of phosphorus per head per day: one half the National Research Council recommendation. Source and amount of phosphorus in the ration were the only variables in the experiment. The treatments by lots were as follows (amount and source of phosphorus per head daily):

Lot 1—Control ration (contained 6 gm. phosphorus).
Lot 2—Control ration plus 3 gm. phosphorus from phosphoric acid.
Lot 3—Control ration plus 6 gm. phosphorus from phosphoric acid.
Lot 4—Control ration plus 3 gm. phosphorus from steamed bone meal.
Lot 5—Control ration plus 6 gm. phosphorus from steamed bone meal.

Blood samples were taken at the end of the wintering phase, and serum calcium and phosphorus levels were determined.

Following the wintering phase, 30 days were allowed for the animals to adjust to hay and grain before the fattening phase was started. The fattening ration consisted of alfalfa hay, sorghum grain, soybean oil meal, salt and a mixture of salt and limestone.

At the beginning of the fattening phase, lots 2, 3, 4, and 5 each were divided into two equal groups, i.e., 2A and 2B. One group, B, continued to receive supplemental phosphorus at the same level as in the wintering phase; the other group, A, did not. At no time in the experiment did the control animals in lot 1 receive supplemental phosphorus.

Carcass grades and marbling scores were obtained after slaughter, and measurements of length, thickness of the bone wall, and diameter, as well as percent ash on dry, fat-free basis, were taken on the right metacarpus. The metacarpus was sawed in half at a point

[1] Contribution No. 256, Department of Animal Husbandry.
[2] This study was supported in part by grants from Westvaco Mineral Products Division, Food Machinery and Chemical Corporation, New York 17, N. Y.
[3] Presently Extension Livestock Specialist, Oklahoma State University, Stillwater.

midway between the distal and proximal ends. The circumference was divided into four equally spaced intervals. The averages of thickness measured between the outer surface and marrow cavity and the average outside diameter were taken at the four equally spaced intervals.

The data were analyzed by analysis of variance. Means were separated by Kramer's (1956) method for the extension of multiple range tests to means with unequal subclass numbers.

Results and Discussion

Wintering Phase. Greater variation in consumption of the corncob-molasses mixture was noted than would be expected with hay or silage. However, the animals never refused to eat. Average daily consumption of the corncob-blackstrap molasses mixture ranged from 9 to 10 lb. per head.

Animals on the high levels of phosphorus supplementation tended to gain more rapidly than those on the control ration or those on low level supplementation; however, differences were not statistically significant between any lots. Differences in response from the two sources of phosphorus were very slight. These results agree with Tillman and Brethour's (1958) comparison of phosphoric acid and dicalcium phosphate.

All lots receiving supplemental phosphorus showed higher serum phosphorus levels than the controls ($P<.01$). Steamed bone meal produced higher serum phosphorus levels than phosphoric acid when both were fed at the 3 gm. per day level ($P<.01$). However, at the 6 gm. per day level there were no significant differences between sources of phosphorus. Serum calcium was significantly higher in the control lot ($P<.01$). All treatment lots had lower percentages of serum calcium. However, differences in serum calcium level between added levels or sources of phosphorus were not significant.

Fattening Phase. In only one case was there a significant difference in gains between the control and any treated lot. Lot 3A, which received 6 gm. phosphorus per day from phosphoric acid on the wintering ration with no supplemental phosphorus during the fattening phase, produced higher gains ($P<.01$) than the control lot or lot 5A, which received the same treatment as 3A except that phosphorus was supplied as steamed bone meal. There were no significant differences in gains of other lots, carcass grade or marbling.

Measurements of the right metacarpus showed no significant differences in length or average diameter due to phosphorus supplementation. A highly significant increase in bone wall thickness was noted in all treatment groups over the control. In the two groups that received 3 gm. added phosphorus, those that received steamed bone meal had significantly thicker bone walls ($P<.01$). When phosphorus was added at 6 gm. per day, there was no difference in thickness of bone wall due to source of phosphorus.

The two lots receiving 6 gm. added phosphorus from phosphoric acid in the wintering phase (3A and 3B) produced lower ash percentages than the other lots. Ash percentage was significantly lower ($P<.05$) than the control for the lot with supplementation only during the wintering phase (3A); however, there was no significant difference between the control and the group (3B) receiving the 6 gm. added phosphorus in both wintering and fattening phases.

No level or source of supplementation caused a large difference in ash percentages.

It is recognized that the phosphorus content of a practical ration should not be as low as the phosphorus content of the control ration in this test; however, the results of this test indicate that the National Research Council phosphorus requirement allows a margin of safety for wintering weanling calves. These results also indicate that supplementary phosphorus is of no value when the animals are receiving a high grain fattening ration.

Summary

Studies with rations containing no supplemental phosphorus and supplemental phosphorus from phosphoric acid or steamed bone meal were conducted with 74 Hereford heifer calves during wintering and fattening phases. There were no statistically significant differences among any of the lots in weight gains during the wintering phase. Supplemental phosphorus increased serum phosphorus over the controls in all cases ($P<.01$). Bone meal produced higher blood phosphorus levels than phosphoric acid when each was fed at 3 gm. phosphorus per day. However, there was no evidence of a difference due to source of phosphorus at the 6 gm. level. Serum calcium was lower ($P<.01$) in all lots receiving supplemental phosphorus. In the fattening phase,

TABLE 1. RESULTS OF WINTERING AND FATTENING, INCLUDING GAINS, CARCASS, BLOOD, AND BONE, DATA ON LEVELS AND SOURCE OF PHOSPHORUS IN BEEF RATIONS

			Wintering phase—154 days				Fattening phase—103 days							
Lot no.	No. animals	Mean initial wt.	Added phos. and source	Mean total gain	Mean Serum Ca	Mean Serum P	Lot	Mean total gain	Mean carcass grade [a]	Mean marbling score [b]	Mean bone length	Mean bone diam.	Mean bone wall thickness	Mean ash
											Right metacarpus			
		lb.	gm.	lb.	mg. %	mg. %		lb.			mm.	mm.	mm.	%
1	10	441	None	162.5	12.23	5.52	1	197.3	11.2	6.6	190.0	30.3	7.1	69.47
2	16	442	3, from phos. acid	170.6	11.41	7.21	2A [c]	216.6	13.6	7.4	194.6	30.9	8.2	69.52
							2B [c]	206.5	13.0	7.4	189.0	30.2	7.7	69.68
3	16	440	6, from phos. acid	182.2	11.41	9.13	3A	241.0	10.5	5.9	193.0	31.4	7.7	68.80
							3B	216.8	11.2	6.4	194.8	30.9	7.8	68.89
4	16	441	3, from st. bone meal	164.5	11.30	8.11	4A	204.5	12.5	6.7	193.5	31.8	9.1	69.32
							4B	200.7	13.5	7.2	195.4	31.2	8.9	69.84
5	16	442	6, from st. bone meal	182.5	11.19	8.94	5A	209.7	10.9	6.3	195.1	31.3	8.2	69.51
							5B	217.9	11.5	6.8	194.0	30.8	7.8	69.92
F	..	...	...	.98	4.04**	34.96**	..	8.60**	1.74	1.87	1.11	1.51	10.73**	3.44*

[a] Carcass grade based on top choice 8, average choice 10, low choice 12, top good 14, average good 16.
[b] Based on slightly abundant 4, moderate 5, modest 6, small amount 7, slight amount 8.
[c] Lots subdivided into groups A and B; group A—supplemental phosphorus discontinued; group B—supplemental phosphorus continued.
* Represents significant values.
** Represents highly significant values.

there was no significant difference in gains due to supplemental phosphorus or source of supplementation except in one case. Phosphorus supplementation increased bone wall thickness ($P<.01$). Steamed bone meal produced thicker bone walls ($P<.01$) than phosphoric acid when fed at 3 gm. phosphorus per day. There were small, but significant ($P<.05$) differences in percent bone ash, with steamed bone meal producing higher ash percentages. It was concluded that phosphoric acid is an acceptable source of supplemental phosphorus.

Literature Cited

Kramer, Clyde. 1956. Extension of multiple range tests to group means with unequal numbers of replications. Biometrics 12:307.

Menzies, C. S. 1956. Sources of phosphorus for beef cattle wintered on dry bluestem pasture. M.S. Thesis, Kansas State University, Manhattan, Kansas.

Richardson, D., F. H. Baker, C. S. Menzies, and R. F. Cox. 1955. Sources of phosphorus for wintering beef heifer calves on dry bluestem pasture. Kans. Agr. Exp. Sta. Cir. 320:48.

Tillman, A. D. and J. R. Brethour. 1958. Dicalcium phosphate and phosphoric acid as phosphorus sources for beef cattle. J. Animal Sci. 17:100.

DIGESTIBILITY STUDIES ON LEVELS OF CONCENTRATES IN COMPLETE PELLETED RATIONS FOR FATTENING LAMBS [1]

B. E. Brent,[2] D. Richardson, W. S. Tsien, and C. S. Menzies

Kansas State University, Manhattan

THE optimum ratio of concentrate to roughage for fattening lambs is important for proper nutrition and economics. Cox (1948) reported the optimum concentrate to roughage ratio for lambs fed a nonpelleted ration to be 45% concentrate and 55% roughage. These results were confirmed by John (1955). Apparently the optimum ratio in pelleted rations differs from that in nonpelleted rations. Work by John (1955), Ross and Pavey (1958) and Joyce (1959) indicates that when a ration is pelleted, the roughage may be increased.

This experiment studied the effects of various concentrate levels in complete pelleted rations on digestion of energy, dry matter and protein, and percent nitrogen retention.

Experimental Procedure

Digestion studies used six different concentrate levels in complete pelleted rations (10, 20, 30, 40, 50, and 60% sorghum grain, respectively) with the remainder of each ration composed of average quality alfalfa hay.

The experimental animals were nine white-faced wether lambs averaging 66 lb. at the beginning of the experiment. The preliminary period consisted of a minimum of 7 days individual feeding in pens and 3 days in collection crates. Lloyd *et al.* (1956) found that 10 days is sufficient to adjust feed intake and for the feces and urine to become representative of the feed, even with a drastic change in concentrate-to-roughage ratio. Seven-day collections were used. A 5% aliquot of urine and feces was obtained daily. The urine was refrigerated with toluene as a preservative. The feces were dried at 100° C. under a vacuum of 29 in. of mercury. All animals received the same ration during each collection period. The 10% concentrate ration was studied first, with the other rations following in order of increasing concentrate percentage.

Nitrogen was determined by standard A. O. A. C. (1955) procedures and energy by combustion in a Parr oxygen bomb calorimeter. Digestible energy was used to evaluate the rations instead of the longer and more complicated method of total digestible nutrients, since studies by Hopson *et al.* (1960) showed a correlation of .96 between digestible energy and total digestible nutrients in pelleted rations.

Results and Discussion

Digestible energy studies on the completely pelleted rations disclosed an essentially linear increase in percent digestible energy as the amount of concentrate in the ration increased. Treatment averages are shown in table 1 and the digestible energy trend line is shown in figure 1. This linear relationship might be expected since the amount of readily available energy increased as the amount of concentrate increased. However, Hopson *et al.* (1960), in a similar study, found a rapid increase in digestible energy as percent concentrate increased from 20 to 30%. Beyond these levels, the percent digestible energy leveled off as the concentrate was increased up to 50%.

Analysis of variance, followed by separation of means by Duncan's multiple range test (Duncan, 1955), indicated that every treatment mean was significantly different from each of the others ($P<.01$). There was a difference at the 5% level between individual lambs in regard to digestible energy. Statistical analysis of the digestible energy trend line showed that a linear relationship accounted for 98.58% of the sum of squares due to treatments.

The close relationship between digestible energy and digestible dry matter is shown in figure 1 and table 1 for the six concentrate levels. The 30% concentrate ration was the only one to show a correlation below .900.

[1] Contribution No. 257, Department of Animal Husbandry, Kansas Agricultural Experiment Station, Manhattan.

[2] Present address: Department of Animal Husbandry, Michigan State University, East Lansing.

TABLE 1. THE EFFECT OF PERCENT CONCENTRATE ON THE UTILIZATION OF COMPLETE PELLETED RATIONS FOR LAMBS

Percent conc.	Dig. energy,		Dig. dry matter,		Protein dig.,		Nitrogen retention,		Correlation dig. energy with dig. dry matter
	Mean	S.D.[a]	Mean	S.D.	Mean	S.D.	Mean	S.D.	
	%	%	%	%	%	%	%	%	
10	60.0	1.4	60.3	1.4	65.7	1.7	—.2	4.1	0.91**
20	65.1	1.8	66.2	1.9	67.0	2.6	1.8	5.1	0.99**
30	67.4	0.9	68.2	0.8	72.0	0.9	13.5	1.8	0.87**
40	70.5	1.2	71.7	1.3	72.9	1.4	20.3	2.0	0.99**
50	72.8	2.4	74.4	2.2	72.6	4.4	27.2	6.5	0.97**
60	77.0	1.9	78.8	1.7	73.0	3.1	23.5	6.3	0.98**
F	139.5**	...	176.6**	...	16.9**	...	55.3**	...	....

[a] Standard deviation.
** Highly significant (P<.01).

The correlation values were shown to be heterogeneous (Snedecor, 1956, p. 178). Hence, the correlation coefficients were not pooled.

Protein digestion coefficients increased from 65.7 on the 10% concentrate ration to 72.0 on the 30% concentrate ration. From this point the trend line leveled off and at 60% concentrate, the protein digestion coefficient was 73.0. Mean separation showed no significant difference between the 10 and 20% concentrate rations or between the 30, 40, 50 and 60% concentrate rations. There was a statistically significant difference (P< .01) between the 20 and 30% concentrate rations, but no significant difference between individual lambs in regard to protein digestion coefficients. In a similar digestion study by Joyce (1959), protein digestion coefficients decreased as percent concentrate in the ration increased.

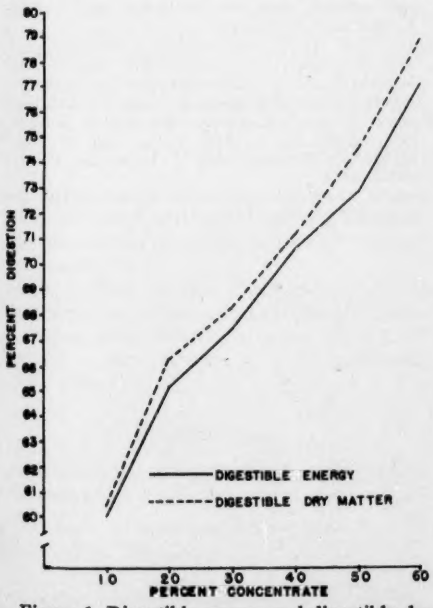


Figure 1. Digestible energy and digestible dry matter on various levels of concentrate in complete pelleted rations for lambs.

Percent nitrogen retained increased as percent concentrate in the ration increased from 10 to 50%, but decreased at 60%. Analysis of variance showed no significant difference in nitrogen retained between the 10% and 20% concentrate rations or between the 50 and 60% concentrate rations. However, highly significant differences (P<.01) were found between the other rations. A negative nitrogen balance for the 10% concentrate ration was obtained (table 1). There was considerable variation in percent nitrogen retained among individual lambs on the same ration. This is shown by the high standard deviations for nitrogen retention. In several cases, apparently healthy lambs were in heavy negative nitrogen balance and others on the same ration were in heavy positive balance. Because of the variations, it appears that nitrogen balance was not an accurate criterion for evaluating rations in this experiment.

The lambs suffered no obvious ill effects from confinement in the digestion crates. Average daily feed intake on the dry matter basis decreased from 1200 gm. per day on the 10% concentrate ration to 840 gm. per day on the 60% concentrate ration. The average gain per lamb during the entire four month experiment was 41 lb. with a standard deviation of 4.5 lb. As is the case with most pelleted rations, the lambs stopped re-

gurgitating soon after being placed on the experiment. They exhibited a craving for normal roughage throughout the study.

Soon after the start of the experiment several lambs began excreting large amounts of urine, in one case 11 l. per day during the 7-day collection period. However, no relationship was found between this polyuria and nitrogen retention, digestible energy, protein digestion coefficients, or weight gains. Those lambs voiding large amounts of urine consumed correspondingly large amounts of water; however, precise water balance records were not kept.

Summary

Digestible energy, dry matter and protein, and percent nitrogen retention were determined in a digestion study with nine lambs fed complete pelleted rations containing 10, 20, 30, 40, 50, or 60% sorghum grain, with the remainder of the ration made up of average quality alfalfa hay. The nine lambs averaged 66 lb. at the beginning of the experiment and 107 lb. at the end.

Highly significant differences ($P<.01$) in digestible energy were found, with digestible energy increasing in an almost perfect linear relationship with increasing concentrate in the ration.

Digestible dry matter was correlated with digestible energy on each individual ration, and a highly significant relationship between the two measurements was found.

Statistical analysis of protein digestion coefficients showed no significant difference between the 10 and 20% concentrate rations or between the 30, 40, 50, or 60% concentrate rations, but a highly significant difference between the 20 and 30% concentrate rations.

Percent nitrogen retained showed a highly significant difference due to rations. Wide variability of percent nitrogen retained between individual lambs on any given ration indicated that nitrogen retention may not be an accurate measurement for the evaluation of the rations studied.

Literature Cited

A.O.A.C. 1955. Official Methods of Analysis (8th ed.). Association of Official Agricultural Chemists. Washington 4, D. C.

Cox, R. F. 1948. Physical balance as a factor in determining the efficiency of feed utilization by fattening lambs. Kans. Agr. Exp. Sta. Tech. Bul. 65.

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics 11:1.

Hopson, J. D., W. S. Tsien, J. A. Joyce, C. S. Menzies and D. Richardson. 1960. Utilization of rations containing different proportions of roughage and concentrate as measured by TDN and DE. J. Animal Sci. 19:910.

John, R. E. 1955. The comparative digestibility and feeding efficiency of pelleted and non-pelleted rations for feeder lambs. M.S. Thesis. Kansas State University.

Joyce, J. A. 1959. Digestion studies on various levels of grain and alfalfa hay fed non-pelleted, pelleted, and pelleted plus hay to lambs. M.S. Thesis. Kansas State University.

Lloyd, L. E., H. E. Peckham and E. W. Crampton. 1956. The effect of change of the ration on the required length of preliminary feeding period in digestion trials with sheep. J. Animal Sci. 15:846.

Ross, C. V. and R. L. Pavey. 1958. Effects of pelleting, concentrate roughage ratios, and hexesterol implants on fattening lambs. J. Animal Sci. 18:1510 (Abstr.).

Snedecor, G. W. 1956. Statistical Methods (5th ed.). Iowa State College Press, Ames, Iowa.

COPPER AVAILABILITY TO SWINE FROM Cu^{64} LABELLED INORGANIC COMPOUNDS [1]

R. G. Buescher, S. A. Griffin [2] and M. C. Bell

University of Tennessee—Atomic Energy Commission Agricultural Research Laboratory, Oak Ridge, Tennessee

THE role of copper in hemoglobin formation in animals was first demonstrated by Hart *et al.* (1928). Reviews on copper were made by Elvehjem (1935), Cunningham (1945), Underwood (1956), Davis (1957) and Matrone (1960). The availability of copper from inorganic copper compounds has had minimal study with growth as the primary criterion. Mills (1957) compared inorganic forms of copper and organic copper complexes in copper deficient rats and found greater response in growth, hemoglobin and liver reserves with the organic copper complexes. Copper sulfate was found to be more available than copper sulfide in swine by Braude (1960). Bunch *et al.* (1960) found copper oxide to be equal to copper sulfate for growth and hemoglobin production in swine but higher liver copper values resulted from feeding copper sulfate than when feeding copper oxide. Copper absorption, tissue concentration and excretion using Cu^{64} as acetate, chloride, nitrate and sulfate have been studied by several workers (Schubert *et al.*, 1948; Comar, 1950; Davis, 1950; Kulwich *et al.*, 1953; Mahoney *et al.*, 1955). Lassiter and Bell (1960) reported copper oxides to be less available to sheep than copper carbonate, chloride, nitrate or sulfate using Cu^{64} labelled compounds.

The purpose of this investigation was to determine the relative availability in swine of copper from different sources, using Cu^{64} labelled cupric carbonate, cupric oxide and cupric sulfate.

Experimental

Fifteen crossbred barrows of similar origin and averaging 35 lb. in weight were placed in individual pens and given feed and water *ad libitum*. After 17 days, nine of these barrows averaging 56 lb. in weight were allotted into three outcome groups according to litter and weight and placed in metabolism units for a 4-day adjustment and preliminary period. Each pig was dosed with 2 millicuries (mc) of Cu^{64} by stomach tube using gelatin capsules containing either copper sulfate, copper carbonate or copper oxide with each dose containing an elemental copper equivalent of 10 mg. The stable copper compounds were labelled with Cu^{64} by thermal neutron activation in the graphite reactor at Oak Ridge National Laboratory using the procedure described by Lassiter and Bell (1960). At the termination of the metabolism study the pigs were placed in individual pens for a 6-day rest and then returned to the metabolism units for a second trial. The same procedure was followed for the second trial except that a different source of copper was given the respective pigs.

The corn-soybean meal ration with no added copper described by Buescher *et al.* (1961) was used. This ration was analyzed to contain 15 ppm copper. Average daily gain, feed consumption and feed per pound of gain were measured during all phases of the experiment.

Blood samples were taken at 1, 2, 4, 8, 16, 24, 36, 48, 72, and 96 hours post-dosing. The first urine and feces samples were collected at 4 hours, then sampling continued on the same schedule as blood sampling. Three ml. each of blood, plasma, and urine and approximately 3 gm. of feces were counted directly in a well-type scintillation counter for Cu^{64} activity.

Results and Discussion

Cu^{64} concentration in blood and plasma, expressed as percent of total dose, is shown in figure 1. The concentration of Cu^{64} in both blood and plasma was similar for copper carbonate, oxide and sulfate with the major

[1] This manuscript is published with the permission of the Director of the University of Tennessee Agricultural Experiment Station, Knoxville, Tennessee. The work was completed under Contract No. AT-40-1-GEN-242 between the University of Tennessee College of Agriculture and the Atomic Energy Commission. The radioactive materials used in this work were obtained from the Oak Ridge National Laboratory on allocation from the U. S. Atomic Energy Commission.

[2] University of Tennessee Agricultural Experiment Station, Knoxville, Tennessee.

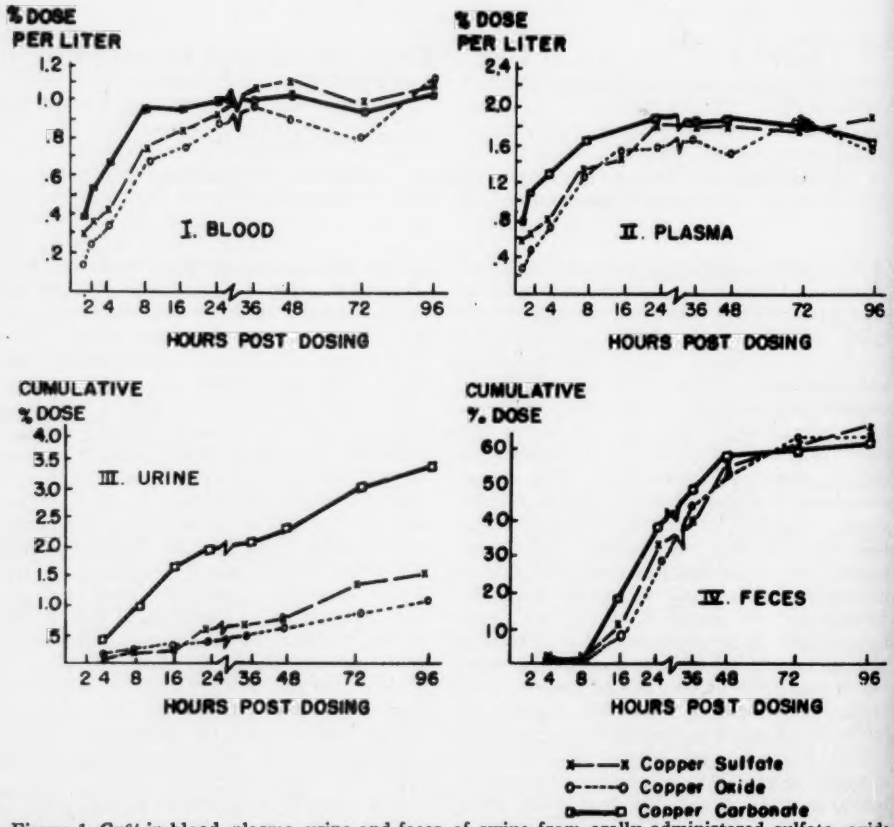


Figure 1. Cu^{64} in blood, plasma, urine and feces of swine from orally administered sulfate, oxide and carbonate.

portion of the Cu^{64} being in the plasma. Eight hours postdosing, the Cu^{64} concentration in blood and plasma began to plateau and remained relatively constant throughout the 96-hour study. As shown in figure 1, the average value of copper carbonate is somewhat higher than the sulfate or oxide through the first 16 hours. However, due to large variations in Cu^{64} activity during the first five sampling periods, these values were not significantly different. The average blood values at 16 hours postdosing were 1.0, 0.9 and 0.8%, and the standard deviations were 0.2, 0.1 and 0.2% of dose/liter for copper carbonate, sulfate and oxide, respectively. These data indicate that the chemical and physical differences of copper carbonate, oxide and sulfate did not influence the absorption of copper in swine.

Schultze *et al.* (1936), using anemic rats, found copper sulfide unavailable, but oxide, hydroxide, iodide, pyrophosphate and some organic sources were readily available. In like manner, Mills (1957) reported copper sulfate more available than insoluble copper sulfide to copper deficient rats. Barber *et al.* (1960) cited data of Bowland *et al.* (unpublished) who found some copper from labelled copper sulfide to be absorbed by pigs, but much more was absorbed when the same amount of copper was given as labelled copper sulfate.

Contrasted to these data, Lassiter and Bell (1960) using Cu^{64} labelled inorganic compounds, found copper oxide to be less available to sheep than copper sulfate or carbonate. This indicates a species difference between ruminants and mono-gastrics. The pH of the intestinal tract of the mono-gastrics being lower than ruminants may enable them to utilize the less soluble forms of copper.

The cumulative fecal and urinary excretions of Cu^{64} are shown in figure 1 and total excretions of Cu^{64} are shown in table 1. There were no significant differences in Cu^{64} fecal output with copper carbonate being 62%, oxide 63% and sulfate 64% of the total administered dose. Approximately 30–35% of the dose was excreted via the feces in the first 24 hours. Cu^{64} from copper carbonate excreted in the urine was higer ($P<0.01$) than from the sulfate or oxide. The total urinary Cu^{64} from carbonate was 3.4% of the dose compared to 1.4% for sulfate and 1.0% for oxide. The increase in copper carbonate urinary excretion may be due to high absorption into the blood. Even though the blood values were not significantly different, the increase in carbonate urinary output may be due to an increase over a threshold level of the kidney, and therefore these pigs excreted more Cu^{64} from the carbonate compound than did the pigs which received copper sulfate or oxide.

Comar (1950) stated that within 5 days after administration of copper to cattle, about 75% was eliminated in the feces and 3% in the urine. In a review on all species by Underwood (1956), it was reported that under normal conditions about 90% of the ingested copper was eliminated in the feces. Likewise, with sheep, Lassiter and Bell (1960) found about 90% of the Cu^{64} eliminated through the feces and 0.5–1.0% in the urine 96 hours following oral dosing. These differences may be due to the rapid growth rate of swine or to differences in dietary levels of copper. However, the dietary level of copper was sufficient to promote good growth in this study.

The average daily gain for the entire experiment was 1.41 lb. with a feed efficiency of 2.5 lb. of feed per pound of gain. While in the metabolism units, the pigs gained well, averaging 1.14 lb. per day with a feed efficiency of 3.0 lb. of feed per pound of gain.

Summary

Nine crossbred barrows were orally dosed with 2 millicuries of Cu^{64} labelled cupric carbonate, cupric oxide, or cupric sulfate. In a second trial the same barrows received a different source of copper. There were no significant differences found in blood or plasma concentration or total fecal output of Cu^{64}. There was a greater ($P<0.01$) amount of copper carbonate excreted via the urine than of copper oxide or copper sulfate. The availabilities of the three forms of inorganic copper compounds for swine were similar.

TABLE 1. EXCRETION AND RETENTION OF Cu^{64} BY SWINE DOSED ORALLY WITH LABELLED COMPOUNDS

Treatment	Cu carbonate	Cu oxide	Cu sulfate
No. of pigs	6	6	5
Feces (% of dose)	61.5	62.8	64.2
Urine (% of dose)	3.4**	1.0	1.4
Retained (% of dose)	35.1	36.2	34.4

** $P<0.01$.

Literature Cited

Barber, R. S., R. Braude, K. G. Mitchell and J. W. G. Porter. 1960. Copper sulfate and copper sulphide as supplements for growing pigs. Proc. Nutr. Soc. 19:xxvi.

Braude, R. 1960. Copper sulfate as a growth promoting additive in the diet of growing pigs. Fifth International Congress of Nutrition, p. 39, (Abstr.).

Buescher, R. G., M. C. Bell and R. K. Berry. 1961. The effect of excessive calcium on selenium-75 in swine. J. Animal Sci. 20:368.

Bunch, R. J., V. C. Speer and V. W. Hays. 1960. Effects of copper oxide, copper sulfate and chlortetracycline on performance of baby pigs. J. Animal Sci. 19:252.

Comar, C. L. 1950. Copper Metabolism. W. D. McElroy and B. Glass, ed. Johns Hopkins Press, Baltimore.

Cunningham, I. J. 1945. The biological functions of copper. New Zealand Sci. Rev. 3:3.

Davis, G. K. 1950. Copper Metabolism. W. D. McElroy and B. Glass, ed. Johns Hopkins Press, Baltimore.

Davis, G. K. 1957. Trace mineral dietary interrelationships. Bordens Rev. Nut. Res. 18:33.

Elvehjem, C. A. 1935. The biological significance of copper as a supplement to iron metabolism. Physiol. Rev. 15:471.

Hart, E. B., H. Steenbock, J. Waddell and C. A. Elvehjem. 1928. Iron in Nutrition. VII. Copper as a supplement to iron for hemoglobin building in the rat. J. Biol. Chem. 77:797.

Kulwich, R., S. L. Hansard, C. L. Comar and G. K. Davis. 1953. Copper, molybdenum and zinc interrelationships in rats and swine. Proc. Soc. Exp. Biol. Med. 84:487.

Lassiter, J. W. and M. C. Bell. 1960. Availability of copper to sheep from Cu^{64} labelled inorganic compounds. J. Animal Sci. 19:754.

Mahoney, J. P., J. A. Bush, C. J. Gubler, W. H. Moretz, G. E. Cartwright and M. M. Wintrobe. 1955. Studies on copper metabolism. J. Lab. Clin. Med. 46:702.

Matrone, G. 1960. Interrelationships of iron and copper in the nutrition and metabolism of animals. Fed. Proc. 19:659.

Mills, C. F. 1957. Dietary factors influencing copper utilization by the animal. J. Sci. Food Agr. 8:588.

Schubert, G., W. Maurer and W. Riezler. 1948. Radioactive tracer studies in copper metabolism. II. Absorption, storage and excretion in animals and man. Z. Ges. Inn. Med. 3:170. (Chem. Abst. 43:3098, 1949).

Schultze, M. O., C. A. Elvehjem and E. B. Hart. 1936. Further studies on the availability of copper from various sources as a supplement to iron in hemoglobin formation. J. Biol. Chem. 115:453.

Underwood, E. J. 1956. Trace Minerals in Human and Animal Nutrition. Academic Press, Inc., New York.

CALCIUM AND CORN OIL INTERRELATIONSHIPS AS INFLUENCING RATION UTILIZATION BY LAMBS[1]

KENNETH L. DAVISON AND WALTER WOODS

Iowa Agricultural and Home Economics Experiment Station, Ames

THE addition of calcium to lamb rations has been shown by White *et al.* (1958) to alleviate the depressing effect of corn oil on digestibility. Tillman and Brethour (1958) found that the addition of 7.5% corn oil reduced the apparent and true digestibility of calcium and resulted in a decrease in calcium retention. Grainger and Stroud (1959) reported that 7% added corn oil decreased apparent digestibility of calcium and increased excretion of fecal soaps. The extent of energy utilization from fat additions is still in question due to the possibility of the fat being excreted as fecal soaps.

The work reported herein was initiated to study the effects of corn oil, corn oil saponified with potassium hydroxide and corn oil plus calcium carbonate upon digestibility of a low ash, high corncob ration fed to lambs. Further studies were conducted to determine the effects of either calcium carbonate, corn oil or starch upon the digestibility of rations containing corncobs or alfalfa hay with emphasis placed upon digestible energy.

Experimental Procedure

Trial 1. Twelve western crossbred wether lambs, weighing an average of 78 lb., were randomly allotted to four groups of three lambs each. The following rations were fed: (1) basal, (2) basal + 40 gm. corn oil per lamb daily, (3) basal + 40 gm. corn oil + 4.5 gm. $CaCO_3$[2] and (4) basal + 45 gm. corn oil previously saponified with KOH[2] at the rate of 5 gm. KOH per 40 gm. corn oil. The basal ration as described by Davison and Woods (1960a) contained: ground corncobs, 46%; ground shelled corn, 32%; corn gluten meal, 20%; salt, 1%; and dicalcium phosphate, 1%. Daily allowance of the basal ration was 800 gm. fed in equal portions twice daily. The trial was repeated with the same lambs being randomly reallotted after a 10-day rest period in which they were fed alfalfa hay. Other digestibility and analytical procedures were similar to those described by Davison and Woods (1960a).

Trial 2. Thirty-two western crossbred wether lambs weighing an average of 70 lb. were randomly divided into eight groups of four lambs each. The lambs were randomly assigned to treatments in which 0, 4, 8 and 12 gm. $CaCO_3$ and 0 and 40 gm. corn oil in a 2 x 4 factorial arrangement were fed daily per lamb. The basal ration was the same as that used in trial 1. Daily allowance of the basal ration was 800 gm. fed in equal portions twice daily. Rations, with the exception of corn oil, were mixed at the beginning of the trial in sufficient quantities for the entire period. Corn oil was added at feeding time. The trial was run in 3 replications with two lambs occurring on each treatment during each replication. Lambs used in replication 1 were randomly reallotted to treatment and used in replication 3 to give a total of six lambs per treatments. The gross energy of the feed and feces was determined with a Parr oxygen bomb calorimeter equipped with an adiabatic jacket. Other procedures were the same as those used in trial 1.

Trial 3. Sixteen western crossbred wether lambs, weighing an average of 80 lb., were randomly allotted to four groups of four lambs each. They were assigned to the following rations: (1) basal, (2) basal + 14 gm. $CaCO_3$ per lamb daily, (3) basal + 40 gm. corn oil, and (4) basal + 14 gm. $CaCO_3$ + 40 gm. corn oil. The basal ration was similar to that used in trial 1 with the exception that any added source of calcium was removed. Corncobs were increased to 47%, salt was decreased to 0.7% and 0.3% NaH_2PO_4 was substituted for dicalcium phosphate. Daily allowance of the basal ration was 800 gm. Corn oil and $CaCO_3$ were added at feeding time. Lambs were placed in all steel stanchion type metabolism stalls designed for separate collection of urine and feces which

[1] Journal Paper No. J-4057 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa. Project No. 1208.

[2] U.S.P. grade of calcium carbonate used in all studies. Reagent grade KOH used to saponify corn oil.

were pattern after those described by Briggs and Gallup (1949). The trial was replicated with the same lambs being randomly reallotted after a 10-day rest period. Calcium was determined on feed and feces by the method of Diehl and Ellingboe (1956) as modified by Tucker (1957). Other analyses were determined as previously described.

Trial 4. Sixteen western crossbred wether lambs weighing an average of 78 lb. were randomly allotted to four groups, each of four lambs. The following rations were fed: (1) basal, (2) basal + 10 gm. $CaCO_3$ per lamb daily, (3) basal + 50 gm. corn oil, and (4) basal + 50 gm. corn oil + 10 gm. $CaCO_3$. The basal ration contained the following: ground corn, 50.0%; alfalfa hay, 40.0%; molasses, 7.0%; soybean meal, 2.4%; and salt, 0.6%. In addition, the daily ration was supplemented with 400 I.U. vitamin A and 50 I.U. of vitamin D_2. The daily allowance of the basal ration was 1000 gm. Other procedures were the same as in trial 3.

Trial 5. Eighteen western crossbred wether lambs weighing an average of 60 lb. were randomly allotted to six groups, each of three lambs. They were fed the following rations: (1) basal, (2) basal + 8 gm. $CaCO_3$ per lamb daily, (3) basal + 40 gm. corn oil, (4) basal + 40 gm. corn oil + 8 gm. $CaCO_3$, (5) basal + 80 gm. corn starch, and (6) basal + 80 gm. corn starch + 8 gm. $CaCO_3$. The basal ration of trial 1 was modified in the present trial by substituting 16% soybean meal for the corn gluten meal, removing 0.5% dicalcium phosphate and adding 4.5% ground corn. Daily allowance of the basal ration was restricted to 800 gm. One lamb on each treatment was placed in a raised wire floor metabolism stall as used in trial 1, and two lambs were placed in steel metabolism stalls as used in trial 3. Other procedures were the same as in trial 3.

The data were treated by analysis of variance. Chemical compositions of the basal rations for the 5 trials are shown in table 1.

Results and Discussion

Trial 1. The results for all trials are given in table 2. Corn oil, corn oil saponified with KOH or corn oil fed with $CaCO_3$ decreased digestibility of organic matter, protein and cellulose ($P<0.01$). Saponifying the corn oil with KOH depressed digestibility of organic matter, protein and cellulose more than corn oil alone. The addition of 4.5 gm. $CaCO_3$ partially alleviated the depressing effects of corn oil upon ration digestibility. Later studies (trial 2) indicated that this level of calcium was probably not high enough to completely overcome the detrimental effects of corn oil. Nitrogen retention tended to be higher in the $CaCO_3$ treatment than in other treatments; however, this was not statistically different.

TABLE 1. AVERAGE CHEMICAL COMPOSITION OF BASAL RATIONS

Trial	Dry matter	Dry matter basis				
		Organic matter	Protein (N x 6.25)	Cellulose	Calcium	Energy Kcal./gm.
1.	91.4	96.4	14.0	24.7	....	....
2. 0 $CaCO_3$	89.7	96.2	14.0	24.8	....	4.57
4 gm $CaCO_3$	89.7	96.0	13.7	25.4	....	4.52
8 gm $CaCO_3$	89.7	95.9	13.3	25.0	....	4.55
12 gm $CaCO_3$	89.8	95.1	13.8	25.7	....	4.48
3.	91.6	97.2	13.2	26.6	0.07	4.55
4.	89.4	95.3	12.9	18.5	0.62	4.54
5.	89.3	96.6	12.8	26.5	0.22	4.54

Lambs fed the ration containing saponified corn oil were very slow in consuming their feed. Lambs fed the ration containing corn oil plus $CaCO_3$ required less time to consume their feed than the lambs on the other treatments.

Trials 2 and 3. Corn oil decreased digestibility of organic matter and cellulose in trials 2 and 3 and decreased digestibility of protein in trial 3 ($P<0.01$). Each successive level of $CaCO_3$ increased digestibility of these ration components in trial 2 and trial 3 ($P<0.01$). Digestibility of organic matter, protein, and cellulose was increased by $CaCO_3$ additions to a greater extent in rations containing corn oil than in the basal rations. Nitrogen retention tended to increase with $CaCO_3$ additions in both trials but this was not statistically significant.

The addition of corn oil decreased the percent of feed energy digested; however, more total calories were digested by lambs fed the

TABLE 2. DIGESTIBILITY, CALCIUM EXCRETION AND NITROGEN BALANCE DATA OBTAINED FROM LAMBS FED CORN OIL, STARCH AND $CaCO_3$[a, b]

Ration	Digestibility			Calcium		N retained		Energy		
	Organic matter	Protein	Cellulose	Intake	Fecal	gm.	% of intake	Feed	Digested	Digestibility
Trial 1	%	%	%	gm.	gm.			Kcal.	Kcal.	%
Basal	70.4	76.6	60.0	..	..	3.06	24.4	..	..	..
+ Corn oil	63.9	72.5	47.0	..	..	3.18	26.8	..	..	..
+ Sap. Corn oil	61.9	71.3	42.2	..	..	3.25	27.9	..	..	..
+ Oil + $CaCO_3$	67.1	75.6	53.4	..	..	3.54	28.7	..	..	..
Trial 2										
Basal	69.1	73.7	58.2		..	3.32	20.8	3265.6	2194.1	67.2
+ 4 gm. $CaCO_3$	73.5	75.4	67.3		..	4.52	27.8	3245.3	2319.6	71.3
+ 8 gm. $CaCO_3$	74.6	74.8	68.5		..	3.73	24.1	3252.8	2365.7	72.7
+ 12 gm. $CaCO_3$	75.6	76.3	73.8		..	4.04	25.3	3208.0	2357.6	73.5
Basal + corn oil	63.9	72.0	48.1		..	3.38	21.4	3642.4	2275.0	62.0
+ 4 gm. $CaCO_3$	65.2	72.6	52.3		..	3.39	21.1	3622.1	2300.8	63.5
+ 8 gm. $CaCO_3$	70.1	75.9	57.5		..	4.07	25.7	3622.1	2478.2	68.4
+ 12 gm. $CaCO_3$	74.3	77.0	69.5		..	4.39	27.6	3584.8	2613.0	72.9
Trial 3										
Basal	68.9	72.8	60.6	0.52	1.13	2.80	18.3	3341.7	2246.6	67.2
+ $CaCO_3$	76.3	77.3	74.5	6.12	4.69	3.44	22.3	3336.0	2477.6	74.3
+ Corn oil	63.9	67.6	50.5	0.51	1.62	2.32	15.1	3712.8	2256.2	60.8
+ Oil + $CaCO_3$	74.3	75.4	69.3	6.00	5.48	3.42	22.6	3726.1	2721.0	73.0
Trial 4										
Basal	77.3	68.6	55.0	6.19	5.57	4.32	23.5	4032.8	3003.5	74.5
+ $CaCO_3$	76.7	68.2	55.0	10.12	9.58	3.89	21.5	4031.3	2990.9	74.2
+ Corn oil	76.5	66.4	55.0	6.20	5.73	4.06	22.1	4511.7	3333.7	73.9
+ Corn oil + $CaCO_3$	77.3	68.2	56.1	10.25	9.52	4.39	23.8	4535.5	3401.6	75.0
Trial 5										
Basal	68.6	73.2	58.2	1.56	1.92	3.16	21.5	3240.0	2154.6	66.5
+ Corn oil	61.2	69.4	39.9	1.56	2.02	2.88	19.7	3620.4	2162.9	59.7
+ Starch	65.8	67.0	48.1	1.56	1.86	3.19	21.7	3538.4	2242.5	63.4
Basal + $CaCO_3$	72.4	74.8	65.6	4.76	3.99	3.35	23.0	3240.0	2274.1	70.2
+ Corn oil	68.8	74.1	57.4	4.76	4.10	3.63	24.7	3620.4	2423.6	66.9
+ Starch	72.4	72.1	61.6	4.76	4.17	3.93	26.6	3538.4	2484.7	70.2

[a] Values are on an average daily basis.
[b] Because of feed refusal certain lambs had to be removed from the treatment. In cases of a small amount of refusal this was weighed, analyzed and subtracted from the amount fed.

corn oil rations than by lambs fed the basal rations ($P<0.01$). The addition of $CaCO_3$ increased the percent digested and total calories digested in both the corn oil and basal rations ($P<0.01$) but gave greater increases in the corn oil rations. The percent of energy digested was nearly as efficient in the high $CaCO_3$, corn oil rations as in the comparable basal rations. Fecal excretion of calcium was increased in trial 3 by the addition of corn oil and/or $CaCO_3$ ($P<0.01$).

Trial 4. Corn oil and/or $CaCO_3$ additions to a ration containing alfalfa hay did not affect digestibility of organic matter, protein or cellulose. Fecal calcium excretion was increased by $CaCO_3$ additions ($P<0.005$) but not by corn oil additions. Nitrogen retention was not affected by any treatment. There was an increase ($P<0.005$) in calories digested by lambs fed corn oil, but the percent digested did not differ significantly.

Trial 5. Corn oil and starch decreased digestibility of organic matter, protein and cellulose whereas $CaCO_3$ increased digestibility of these components in all rations ($P<0.005$). The addition of $CaCO_3$ increased digestibility of organic matter and cellulose to a greater extent in rations containing corn oil or starch than in the basal ration and completely counteracted the depressing effect of starch upon digestibility of organic matter. Corn oil had greater depressing effects upon digestibility of organic matter and cellulose than starch; however, starch depressed protein digestibility more than corn oil. Fecal calcium was increased by addition of $CaCO_3$ to the ration ($P<0.005$). The addition of $CaCO_3$ increased the retention of nitrogen ($P<0.005$).

The addition of $CaCO_3$ increased digestibility of energy in all rations ($P<0.005$). Digested calories were not increased by the addition of corn oil to the basal ration; however, digested calories were increased when corn oil was fed in combination with $CaCO_3$. An increase occurred in digested calories when starch was added and was further increased by $CaCO_3$ addition.

Saponification of corn oil with KOH failed to alleviate its depressing effects. Brethour *et al.* (1958) found potassium and sodium bicarbonates ineffective in alleviating the effects of corn oil. Calcium carbonate was

effective in counteracting the detrimental effects of corn oil upon ration digestibility. It would appear from these studies, which support the findings of White *et al.* (1958), that calcium is effective in overcoming the detrimental effects of fat on digestibility of a low ash ration.

In general, digestion coefficients obtained with lambs fed the low calcium, corncob ration in trial 3 do not appear to be different from those obtained with lambs fed the adequate calcium rations in trials 1, 2 and 5, with the exception of ether extract (not reported) which tended to be lower in the low calcium ration than in other rations. Apparently the calcium supplied by dicalcium phosphate in trials 1, 2 and 5 had little or no effect upon ration digestibility. Byers (1959) reported that calcium increased digestibility of alfalfa hay by steers when fed as $CaCO_3$ but only slightly increased digestibility when fed as dicalcium phosphate. Whether this is due to the quantity of calcium provided or to some other reason is unknown.

Calcium carbonate not only increased digestibility of rations containing corn oil but also increased digestibility of the basal rations with the exception of the alfalfa hay ration used in trial 4. White *et al.* (1958) reported that $CaCO_3$ alleviated the depressing effects of corn oil but did not increase digestibility of the basal ration which led them to believe that the basal ration was adequate in calcium. However, their basal ration was of a semi-purified type containing 65% corncobs as the only natural ingredient and was calculated to contain 0.37% calcium whereas the rations used in trials 1 and 2 were calculated to contain 0.3% calcium. Neither $CaCO_3$ nor corn oil altered digestibility of the alfalfa hay ration which contained 0.62% calcium. Work at this station (Davison and Woods, 1960b) indicates that calcium as the carbonate or the chloride will increase digestibility of rations containing corncobs and corn oil. Calcium will not only alleviate the depressing effects of corn oil but appears to be an important factor in the digestibility of natural feedstuffs under certain conditions.

Digestible energy data indicate that the energy from corn oil is well utilized when the ration contains alfalfa hay but not when the ration contains corncobs without proper calcium supplementation. When calcium is added to a level approximating that of the alfalfa hay ration (0.6% calcium) or higher, then the energy is well utilized in rations containing corncobs. The energy from corn oil is approximately 70% digested if it is assumed that the increase in digested calories for lambs fed corn oil compared to those not fed corn oil in rations containing alfalfa hay or corncobs + $CaCO_3$ is due to an increased digestion of the energy from corn oil.

Summers *et al.* (1957) showed that starch decreased digestibility of cellulose in a semi-purified ration and that this could be alleviated by the addition of alfalfa ash or trace minerals. In trial 5, $CaCO_3$ increased digestibility of the ration containing starch.

An interesting observation was that nitrogen retention tended to increase as $CaCO_3$ was added to the rations. Summers *et al.* (1957) noted a similar increase when alfalfa ash was fed with rations containing corn oil.

Summary

A series of digestibility studies were conducted with lambs to study the effects of corn oil, corn oil saponified with KOH, $CaCO_3$, corn oil + $CaCO_3$, starch and starch + $CaCO_3$ upon digestibility of rations containing corncobs or alfalfa hay. Corn oil or starch decreased digestibility of these components in corncob rations. $CaCO_3$ increased digestibility of organic matter, protein and cellulose to a greater extent in rations containing corn oil than in controls. Additions of $CaCO_3$ increased fecal calcium in all instances where this was measured. Calcium tended to increase nitrogen retention. The addition of $CaCO_3$ increased the calories digested from corn oil or starch additions to corncob rations. Energy from corn oil was not efficiently utilized when the ration contained less than 0.3% calcium. Corn oil or calcium did not appear to alter digestibility of a ration containing alfalfa hay. The energy from corn oil was well digested by lambs when incorporated in the alfalfa hay ration.

Literature Cited

Brethour, J. R., R. J. Sirny and A. D. Tillman. 1958. Further studies concerning the effects of fats in sheep rations. J. Animal Sci. 17:171.

Briggs, H. M. and W. D. Gallup. 1949. Metabolism stalls for wethers and steers. J. Animal Sci. 8:479.

Byers, J. H. 1959. The digestibility of alfalfa hay by dairy steers as influenced by calcium and phosphorus supplements. J. Dairy Sci. 42:935 (Abstr.).

Davison, K. L. and W. Woods. 1960a. Influence of fatty acids upon digestibility of ration components by lambs and upon cellulose digestion *in vitro*. J. Animal Sci. 19:54.

Davison, K. L. and W. Woods. 1960b. Influence of minerals and fat additions upon ration digestibility

and performance of fattening lambs. J. Animal Sci. 19:1256 (Abstr.).
Diehl, H. and J. L. Ellingboe. 1956. Indicator for titration of calcium in presence of magnesium using disodium dihydrogen ethylenediamine tetraacetate. Anal. Chem. 28:882.
Grainger, R. B. and J. W. Stroud. 1959. An effect of neutral fat, calcium and corn distillers dried solubles on roughage utilization by ruminants. Proc. Dist. Feed. Con. 14:16.
Summers, C. E., F. H. Baker and R. B. Grainger. 1957. Cellulolytic interrelationships of carbohydrates, fat and trace minerals in sheep rations. J. Animal Sci. 16:781.
Tillman, A. D. and J. R. Brethour. 1958. The effect of corn oil upon the metabolism of calcium and phosphorus by sheep. J. Animal Sci. 17:782.
Tucker, B. M. 1957. Calcein as an indicator for the titration of calcium with ethylenediaminetetraacetate. Analyst. 82:284.
White, T. W., R. B. Grainger, F. H. Baker and J. W. Stroud. 1958. Effect of supplemental fat on digestion and the ruminal calcium requirement of sheep. J. Animal Sci. 17:797.

EFFECT OF HYGROMYCIN FED TO SWINE UNDER TWO SYSTEMS OF MANAGEMENT[1]

A. J. Clawson, H. L. Miller, E. G. Batte, C. Z. McSwain and J. L. Rea, Jr.[2]

North Carolina Agricultural Experiment Station, Raleigh

THE usefulness of an anthelmintic depends upon its ability to remove parasites without causing harm to the host animal. In order to justify the cost of treatment, the anthelmintic should either increase production of the animals being treated or reduce parasitism of future inhabitants. Conrad and Beeson (1958), Sewell *et al.* (1959), Teague *et al.* (1958), Thomas *et al.* (1959), and Wingert (1958) have all reported that the antibiotic hygromycin was effective in the control of specific internal parasites of swine. Thomas *et al.* (1959) and Sewell *et al.* (1959) have reported that the feeding of hygromycin does not prevent the liver damage resulting from migrating ascarid larva. Even though the ascarids are nearly eliminated from the intestinal tracts of hygromycin fed pigs, the growth response obtained from feeding this anthelmintic to pigs has been variable. Conrad and Beeson (1958), Teague *et al.* (1958) and Wahlstrom (1959) have obtained a growth stimulus from feeding hygromycin to young pigs to weights of approximately 100 lb. but growth has been depressed when hygromycin was fed to heavier pigs. Wahlstrom (1959) found that hygromycin increased daily gain when fed to both wormed and non-wormed pigs on concrete, but not on pasture. Similar results were obtained by Thomas *et al.* (1959).

The objectives of the experiment described herein were: (1) to study the effect of continuous feeding of hygromycin to sows during the latter part of gestation and early lactation on their reproductive performance and on livability of their offspring when raised either in confinement or on pasture; (2) to study the effect of continuous feeding of hygromycin in starting and growing rations (to a weight of approximately 100 lb.) on growth, feed requirements, liver scars and ascarids harbored by market hogs.

Procedure

Experiment I. A total of 38 second-litter sows were used during 2 fall seasons to study the effects of hygromycin on the performance of litters from sows fed this antibiotic. The sows were maintained on Ladino clover pasture during gestation and were fed 3 lb. of the following mixed ration per head daily: ground shelled corn 73.75, soybean meal 12.50, dehydrated alfalfa meal 6.25, meat scraps 6.25, ground limestone 0.44, defluorinated phosphate 0.37, and salt 0.44%.

Thirty days prior to farrowing the sows were divided into two treatment groups. One group was continued on 3 lb. of control ration. The other group was fed 3 lb. of a similar ration to which hygromycin had been added at the rate of 16 mg. per lb. which provided 48 mg. per sow per day. This level of hygromycin was fed during the 30 days prior to and for 21 days after farrowing. The sows were farrowed in crates in a central farrowing barn. Approximately 3 weeks after farrowing, the sows and litters in each group were divided and placed either on Ladino clover-fescue pasture or on pens with concrete floors. The pasture consisted of two 2-acre lots which had been used for swine only once 2 years previously. The concrete feeding platforms were newly built. The pasture pigs were housed in open-front sheds similar to those used on the concrete platforms except for dirt floors. No bedding was used for either group.

The pigs were creep-fed the following starter ration: ground yellow corn 69.25, soybean meal 11.5, dried skim milk 11.5, dehydrated alfalfa meal 3.0, yellow grease 2.0, trace mineral salt 0.5, defluorinated phosphate 1.0, limestone 0.7 and a vitamin antibiotic supplement 0.55% which supplied the following per ton: vitamin A 1,000,000 U.S.P. units, vitamin D_2 1,000,000 U.S.P. units, vitamin E 1,000 I.U., riboflavin 3 gm., pantothenic acid 8 gm., niacin 20 gm., choline chloride 100 gm., vitamin B_{12} 10 mg., and arsonilic acid 90 gm.

[1] Approved for publication as paper no. 1275 in the Journal Series of North Carolina Agricultural Experiment Station.

[2] The authors wish to acknowledge the assistance of Eli Lilly & Company; Indianapolis, Ind.; and Charles Pfizer & Company, Terre Haute, Ind., for materials which partially supported this research.

Pigs from sows that received hygromycin also received this antibiotic in their creep ration. Hygromycin was supplied for these pigs at the rate of 12 gm. per ton.

After being moved from the farrowing barn, the sows were self-fed shelled corn and 55% digester tankage during the first season and a supplement composed of equal parts of 55% meat scraps, 36% cottonseed meal and 44% soybean meal plus 7.5% dehydrated alfalfa meal, 1.0% trace mineral salt and 2.5% vitamin antibiotic supplement which supplied four times the level used in the creep ration listed above during the second season. Water was provided by automatic drinking cups.

At weaning, four lots of pigs were maintained but they were redivided so that one-half of the pigs raised on concrete during the pre-weaning period were placed on pasture and one-half of the pasture fed pigs were placed on concrete. This applied to both the control and hygromycin fed groups. After weaning, hygromycin feeding was continued for those pigs whose dams had received this antibiotic. These pigs had also received hygromycin in their starter ration.

The ration consisted of shelled corn and supplement which was fed free choice. The supplement used was the same as the one listed above for feeding the sows and litters during lactation. Hygromycin was added to the supplement at the rate of 48 gm./ton for those pigs that received this antibiotic. Hygromycin was fed until the pigs in the respective lots averaged approximately 100 lb. The corn used during the first season was field damaged and of poor quality.

The pigs were weighed at 28-day intervals and feed consumption was recorded. They were slaughtered at a weight of approximately 190 lb., at which time the small intestine of each pig was stripped and mature ascarids counted. An estimate of parasite damage to the livers was also obtained by counting the scar tissue spots observable on the surfaces. Backfat thickness and carcass length were measured on the warm carcass and tracings of a cross section of the rib eye muscle at the 13th rib were made after a 24-hour chill.

Experiment II. One hundred and thirty-four 10-week old, 45-lb. pigs that had previously received hygromycin in their creep rations were used. They were divided by litter and sex, and were fed the following ration either with or without added hygromycin: ground yellow corn 40, ground milo 40 and protein supplement 20%. This ration was calculated to contain 16% crude protein initially and was adjusted to 14 and 12% protein when the pigs averaged approximately 75 and 125 lb. live weight, respectively. Yellow corn replaced the milo at the time the rations were changed from 16 to 14% crude protein. The rations were self-fed and automatic waterers were provided. The feeding of hygromycin was discontinued at the time the pigs weighed approximately 125 lb. The pigs were weighed and feed consumption records made at 4-week intervals.

Two rape pastures of approximately 2 acres each were used. Trees were available for shade and sprinklers were used for cooling. The pigs were handled at slaughter as in Experiment I with the exception that tracings of loin eye area were not obtained.

Results and Discussion

Experiment I. The farrowing and lactation performance of the sows and performance of the litters to weaning are presented in table 1. Average number of pigs farrowed per litter (9.2 and 10.1 for the control and hygromycin-fed sows respectively) did not appear to be influenced by the low level feeding of hygromycin for 30 days prior to farrowing. Average birth weights for the two respective treatments were 2.72 and 2.62 lb. This difference may be attributed at least in part to variations in litter size. Means *et al.* (1958) reported no adverse effect on reproductive performance from feeding hygromycin to swine.

Total concentrate fed per pig farrowed was low (average 38 lb.) as a result of the low level of feeding during gestation. The percent of the pigs farrowed that were weaned was high for both the control and hygromycin fed sows, and for sows and litters maintained on concrete or on pasture, for both years.

Starter consumption was higher for the control pigs fed both on concrete and on pasture. This difference was particularly marked during the first season. Because of group feeding, a statistical analysis of creep-feed consumption was not feasible. Hygromycin apparently reduced the palatability of the starter ration. Part of the difference in creep-feed consumption may have been associated with litter size. Allen and Lasley (1960) obtained a positive correlation between milk production of the sow and the amount of creep feed con-

TABLE 1. FARROWING AND LACTATION PERFORMANCE OF SOWS FED ON CONCRETE OR ON PASTURE AND FED RATIONS WITH OR WITHOUT HYGROMYCIN

Item	Control		Hygromycin	
	1957	1958	1957	1958
Number of sows[a]	9	9	10	10[b]
Av. no. pigs farrowed	9	9.4	11.2	9
Av. birth wt./pig, lb.	2.8	2.6	2.7	2.6
Total feed/pig farrowed, lb.	40	38	32	42

Treatments started at the time the pigs averaged 18 days of age.

Item	Control				Hygromycin			
	Concrete[c]		Pasture		Concrete		Pasture	
Number of litters	4	4	5	5	5	5	5	4
Av. no. pigs started/litter	9.0	7.0	7.6	7.6	10	7.6	10.6	7.0
Av. wt./litter at weaning, lb.	310	224	289	279	328	253	337	263
Av. wt./pig at weaning, lb.	35	33	39	39	34	34	34	38
Av. no. pigs weaned/litter	8.8	6.8	7.4	7.2	9.8	7.4	10.0	6.8
Feed record during lactation								
Creep feed consumed/pig weaned, lb.	28	26	27	25	21	22	18	26
Av. daily creep feed consumed per pig, lb.	0.80	0.63	0.76	0.61	0.61	0.60	0.52	0.59
Total feed consumed/sow and litter during lactation, lb.	976	1037	877	878	830	776	869	895
Av. % protein consumed	24	19	19	20	24	20	22	18
Total feed/pig weaned[d], lb.	133	217	168	169	122	151	123	214

[a] All second-litter sows rebred at time spring litters were weaned.
[b] One sow fed hygromycin farrowed only two pigs, both of which were dead.
[c] Represents 1957 and 1958 observations, respectively.
[d] Includes feed consumed during gestation and lactation.

sumed by her litter. Average litter weight and average weight per pig at weaning were not significantly influenced by treatment. Likewise, percent of pigs weaned of those farrowed did not appear to be associated with hygromycin feeding or with confinement vs. pasture feeding.

Total feed per pig weaned was low (range 122 to 217 lb.). Inasmuch as this includes all supplemental feed consumed by the sows during gestation and lactation and starter ration consumed by the pigs, it would not be expected to be influenced by the ration treatments imposed. The feed saving which resulted from pasture vs. confinement feeding to weaning was small (average of 35 lb. of feed saved per cwt. of gain per sow and litter). The sows fed the corn-tankage ration free choice on concrete apparently had satisfactory milk production but did not gain while the sows on pasture gained an average of 40 lb. each (average for one year). Protein supplement consumption by the sows and litters (table 1) when fed free choice during lactation was high and may result at least in part from supplement consumption by the pigs.

The results obtained during the post-weaning period are presented in table 2. Pigs fed hygromycin and those fed on pasture consumed less feed than pigs fed the control rations and those fed on concrete. As was stated previously, because of group feeding, it was not feasible to test feed intake for statistical significance. The lower feed intake reflected in slightly lower average daily gains for pigs receiving hygromycin and for pigs fed on pasture. The lower feed consumption for groups previously fed hygromycin (note feed consumption to 56 days, table 2) persisted on to market weight. Previous observations at this station (Clawson and Galvin, 1958) indicate that pigs fed hygromycin consumed less feed even during the period from 40 to 75 lb. live weight than did control pigs. Thrasher *et al.* (1958) reported no improvement in daily gain or in feed efficiency when previously nonwormed pigs were fed hygromycin at the rate of 6 mg. per lb. of feed. Daily gain was depressed when hygromycin was fed to previously wormed pigs. Levels of 3, 6 and 12 mg. of hygromycin B per lb. of total feed were also compared by Thrasher *et al.* (1958) and a depression in feed intake and daily gains occurred in pigs fed the 12 mg. level. It

TABLE 2. POST-WEANING PERFORMANCE OF PIGS FED ON CONCRETE FLOORS AND ON PASTURE AND FED RATIONS WITH OR WITHOUT HYGROMYCIN

Item	Control				Hygromycin			
	Concrete[a]		Pasture		Concrete		Pasture	
No. pigs started	36	27	41	36	49	37	47	28
Av. starting wt., lb.	38	33	36	39	32	34	32	38
Av. final wt., lb.	190	183	190	187	187	182	189	182
Av. daily gain, lb.								
First 56 days	1.23	0.86	1.10	0.74	1.12	0.75	1.10	0.71
To final wt.	1.23	1.21	1.22	1.18	1.09	1.07	1.14	1.10
Av. daily feed, lb.								
First 56 days	4.31	2.83	3.61	2.88	3.67	2.81	3.35	3.32
To final wt.	5.42	4.68	4.57	4.45	4.53	4.37	4.45	4.21
Feed/lb. gain, lb.								
First 56 days	3.51	3.30	3.28	3.91	3.28	3.76	3.05	3.26
To final wt.	4.42	3.87	3.76	3.79	4.14	4.08	3.92	3.83
Av. percent protein consumed, %	16.2	16.1	16.0	15.3	15.7	15.5	15.5	15.3
Slaughter data								
No. pigs slaughtered[b]	36	21	38	21	47	15	44	24
Av. age of pigs at slaughter, days	178	175	181	182	196	187	189	176
Av. live wt. of pigs slaughtered, lb.	195	188	191	190	187	188	190	190
Warm carcass wt., lb. (head on, leaf in)	149	144	148	144	147	145	147	138
Carcass length, in.	29.2	29.6	28.9	29.2	29.4	29.5	29.3	29.4
Av. backfat thickness, in.	1.61	1.74	1.56	1.72	1.50	1.71	1.51	1.74
Av. area of loin eye, sq. in[c]	4.20		3.88		4.00		3.93	
Av. no. liver scars	10.5	15.6	8.0	10.4	4.3	18.2	9.5	14.9
Av. no. mature ascarids	13.4	12.3	11.2	28.3	3.9	0.2	5.0	5.9

[a] Represents 1957 and 1958 observations, respectively.
[b] In 1957, 87 percent of pigs farrowed were marketed, in 1958, 68 percent. Carcass data were not obtained for the first 27 pigs reaching market weight in 1958.
[c] Measured on the left side at the tenth rib.

should be noted, that hygromycin was fed throughout these trials.

The pigs fed on pasture required less feed per 100 lb. of gain than those fed on concrete floors. This advantage for pasture was manifest even though the protein supplement fed to both groups was well fortified with known required vitamins and minerals. Average protein supplement consumption was high, probably resulting from the poor quality corn fed, and it was not affected by treatment. There was no measurable difference in post-weaning gains between pigs raised pre-weaning on pasture or on concrete floors; therefore, the data are presented only by post-weaning treatments in table 2.

Even though the feeding of hygromycin was discontinued at the time the pigs averaged approximately 100 lb., the intestinal tracts of the hygromycin-fed pigs contained fewer mature ascarids at market weight than did the control pigs ($P<0.05$). Average number of ascarids recovered was 15 and 4, respectively. This was true for pigs fed on concrete as well as those fed on pasture.

There was also a reduction in number of liver scars in the pigs fed hygromycin on concrete during the first year. This was not true for pigs fed hygromycin on pasture. Results of the second year's work showed that livers of pigs fed hygromycin both on concrete and on pasture had more scar tissue spots than did the control pigs.

Sewell *et al.* (1959) and Thomas *et al.* (1959) obtained no difference in the number of livers condemned or in number of liver scars between control and hygromycin-fed pigs when examined at slaughter. Apparently, hygromycin is effective in eliminating a high percent of mature ascarids from the intestinal tract of pigs but is not effective in preventing the ascarid larva from making its migratory cycle to the liver and lungs where a high percentage of damage takes place. It is also

possible that a part of this damage could have occurred after the use of hygromycin was discontinued.

The data were combined for the 2 years for obtaining correlations. The correlations between number of mature ascarids recovered at slaughter and number of liver scar tissue spots, and between number of mature ascarids and daily gain were low (γ=0.05 and γ=0.02, respectively). The correlation (γ=—.22) between number of liver scars and average daily gain was statistically significant ($P<0.01$). Even though this correlation was significant, the variance associated with liver scar tissue spots accounts for only about 5% of the difference in rate of gain.

Lasley (1951) showed, in a series of trials, that worming growing pigs with sodium fluoride did not result in increased rate and economy of gains following treatment. On the contrary, the pigs in the non-wormed lots actually made 3.5% more rapid gains and required 2.1% less feed per unit of gain. In an extensive study involving the use of 120 wormed and non-wormed pigs, Wahlstrom (1959) reported no benefit from worming pigs with sodium fluoride. In fact, non-wormed pigs gained significantly faster than pigs that had been wormed. Wahlstrom stated that the setback incurred as a result of worming at 40 lb. may not have been completely overcome during the period from 40 to 100 lb.

This work is in agreement with results reported by Clawson and Bell (1957), Kelly *et al.* (1956) and Wingert (1958). These workers were unable to show any benefit in daily gains as a result of worming pigs with cadium anthrenolate, sodium fluoride or piperazine. In fact 40 lb. pigs wormed once (Clawson and Bell, 1957) at the initiation of the trial with these three compounds consumed only 1.48, 1.72 and 1.82 lb. of feed daily for the 5-day period following worming as compared to 2.15 lb. per day for control non-wormed pigs. It required more than 3 weeks for the wormed pigs to equal daily gains of the controls and there was no significant difference between treatments in daily gains for the 100-day feeding period following treatment.

These studies would indicate that ridding the growing pig of mature ascarids does not improve his performance. Because of the fact that ascarid prevention in swine is very difficult in practice, worming agents are apparently still needed to help prevent the rapid build up of ascarid eggs. It is unfortunate that there is not a systemic anthelmentic for swine that will destroy the parasite larva before the tissue damage to the organs takes place.

The carcass traits, backfat thickness, carcass length and area of loin eye were not affected by ration treatment. There was a trend toward larger loin lean areas in pigs fed on concrete (data for 1 year only). There was apparently no detrimental effect on carcass quality as a result of feeding on concrete floors where exercise was limited.

Experiment II. In this trial there were no differences in daily feed intake, rate of gain, or feed per pound of gain associated with treatments. A summary of these data is presented in table 3. Daily gains of 1.57 and 1.54 lb. for the control and hygromycin pigs are more satisfactory than were obtained in Experiment I with inbred pigs. In this trial there was some feed wastage which may account for the high feed requirement. Griffin and Chamberlain (1959) fed hygromycin to wormed and non-wormed pigs and obtained no significant difference in daily gain or in feed per 100 lb. of gain as compared to control pigs.

TABLE 3. PERFORMANCE OF PIGS FED RATIONS WITH AND WITHOUT HYGROMIX ON RAPE PASTURE

Item	Control	Hygromix
No. pigs per lot	67	67
Av. initial wt., lb.	45	46
Av. wt., 63 days on test, lb.	143	144
Av. final wt., lb.	190	188
Av. daily gain, lb.		
First 63 days	1.57	1.55
To final wt.	1.57	1.54
Av. daily feed, lb.		
First 63 days	5.54	5.58
To final wt.	6.08	6.16
Feed per cwt. gain, lb.		
First 63 days	353	359
To final wt.	386	399
Slaughter data		
No. of pigs slaughtered[a]	51	59
Av. age of pigs at slaughter, days	167	168
Av. no. of liver scars	7.3	6.4
Av. no. of mature ascarids recovered from the small intestines	5.5	1.8

[a] 23 gilts were kept for replacement and 2 pigs died during experiment.

Pigs fed hygromycin post weaning harbored significantly fewer ($P<0.05$) mature ascarids at market time than pigs fed the control ration (average 1.8 and 5.5 ascarids respectively). Hygromycin fed in the creep ration of

all pigs was apparently not effective in prevention of ascarid invasion at a later date. The average numbers of liver scars for the same two treatments were 6.4 and 7.3 respectively, a difference which was not statistically significant. Correlations between the number of mature ascarids and the number of liver scars, and between number of mature ascarids and rate of gain were low and not significant. A significant negative correlation between number of liver scars and average daily gain was observed. The data for liver scars and daily gains from pigs in Experiments I and II were combined to obtain correlation coefficients. This correlation (γ=—0.25) involving 360 observations for each variable was highly significant ($P<0.01$).

At the time the pigs had been on experiment 46 days, it was noted that pigs in the hygromycin fed group appeared to have impaired hearing. It was observed that pigs in the control lot responded to the sound of an auto horn by a show of activity, while the hygromycin fed pigs paid no attention. This lack of response of the hygromycin fed pigs to the sound of the auto horn persisted until the pigs were slaughtered, even though the feeding of hygromycin was discontinued about 6 weeks previously. No further tests were made to determine if the pigs were actually deaf.

Summary

A total of 38 second-litter sows and their litters were used to study the effect of continuous feeding of hygromycin to sows during the last 30 days of gestation and the first 21 days of lactation on reproductive performance and on livability and performance of their offspring.

The feeding of hygromycin during the last 30 days of gestation had no apparent effect on reproduction. Its use in the diet of lactating sows and nursing pigs was of no apparent benefit in improving weaning weights or survival. The pigs receiving hygromycin consumed less starter feed. The feeding of hygromycin in the protein supplement fed free choice or in complete mixed rations to pigs from weaning to a weight of approximately 100 lb. did not affect growth rate or feed efficiency. This was true for pigs fed either in confinement or on pasture.

Examination of the intestinal tracts at the time of slaughter (approximately 190 lb.) showed that pigs that had received hygromycin for the period from weaning to 100 lb. in weight harbored fewer ascarids. However, liver damage associated with ascarid larval migration was not affected by feeding hygromycin. A statistically significant negative correlation (γ=—.25) between number of liver scars and average daily gain was observed. Low and non-significant correlations were observed between daily gain and number of mature ascarids and between number of liver scars and number of mature ascarids recovered at slaughter. It was observed that pigs fed hygromycin during Experiment II developed impaired hearing.

Literature Cited

Allen, A. D. and J. F. Lasley. 1960. Milk production of sows. J. Animal Sci. 19:150.

Clawson, A. J. and R. Bell. 1957. Save this bag of feed. Research and Farming. N. C. Agr. Exp. Sta. 15:10.

Clawson, A. J. and T. J. Galvin. 1958. The influence of feeding an Anthelmintic (hygromix) on the performance of growing pigs. Assoc. of Southern Agr. Workers Proc. 55:85.

Conrad, J. H. and W. M. Beeson. 1958. Effect of hygromycin and a combination of antibiotics on growing-finishing swine. J. Animal Sci. 17:1175.

Griffin, S. A. and C. C. Chamberlain. 1959. Value of hygromycin B as an antibiotic and as an anthelmintic for swine. J. Animal Sci. 18:1161.

Kelley, G. W., L. S. Olson and V. Garwood. 1956. A field evaluation of ascaricides in swine. Vet. Med. 51:97.

Lasley, J. F. 1951. The influence of the sodium fluoride treatment for roundworms on subsequent rate and economy of gains in swine. Mo. Agr. Exp. Sta. Progress Rept. 16, p. 18.

Means, T. M., C. F. Chappel, D. I. Gard, W. P. Waitt and J. F. Downing. 1958. A study of the effect of hygromix on the reproductive performance of boars. Assoc. Southern Agr. Workers Proc. 55:86.

Sewell, R. F., R. W. Shackelford and J. L. Carmon. 1959. Effects of hygromycin B in preventing internal parasite infestation and carcass damage in growing swine. J. Animal Sci. 18:1161.

Teague, H. S., H. R. Smith and E. A. Rutledge. 1958. Hygromycin B and piperazine phosphate as worming agents for swine and their influence on performance when fed continuously. Ohio Agr. Exp. Sta. Mimeo, 112.

Thomas, H. R., D. F. Watson, R. F. Kelly and C. C. Brooks. 1959. Effects of hygromycin, aureomycin, sodium fluoride treatment and system of production on growing swine. Va. Agr. Exp. Sta. Bul. 508.

Thrasher, D. M., H. Theilen, P. B. Brown and Sam L. Hansard. 1958. Effects of aureomycin and hygromycin B on wormed and non-wormed pigs. J. Animal Sci. 17:1175.

Wahlstrom, R. C. 1959. Effect of sodium fluoride and hygromycin on growing-finishing pigs. J. Animal Sci. 18:1067.

Wingert, F. C. 1958. Studies with growing-fattening swine: anthelmintics. Proc. Univ. of Md. Nutrition Conf.

SPACE ALLOTMENT AND PERFORMANCE OF GROWING-FINISHING SWINE RAISED IN CONFINEMENT [1]

HUBERT HEITMAN, JR.,[2] LEROY HAHN,[3] C. F. KELLY [2] AND T. E. BOND [3]

University of California and United States Department of Agriculture, Davis

THE present trend towards raising hogs in confinement has emphasized the lack of basic information on the amount of space required by growing-finishing swine raised in this manner. Recommendations of about 16–35 sq. ft. per pig are often presented (Bond and Peterson, 1958).

One test (Noland *et al.*, 1959) reported that 16 sq. ft. per pig is more desirable than 8 sq. ft. and that 24 sq. ft. is of no more advantage.

The need for more definite information on such an important problem stimulated this project.

Experimental

It is possible to vary space allotment experimentally by changing the physical size of pens of equally numbered groups of hogs or to vary the number of hogs per group in equally size pens. Since it was considered possible that the number of hogs per pen *per se* might also affect results, both methods of varying space allotment were used. Consequently, the experiment was planned with a 3 x 3 factorial design with space allotments of 5, 10 and 20 sq. ft. per hog and hog groups of 3, 6 and 12 each. Two replicates were completed during the summer of 1959 and the winter of 1959–60 with 70- and 68-day experimental periods, respectively.

The animals were housed in pens in the University central farrowing barn. The floor was concrete, and the dividing fences were of spaced lumber. No outdoor pen was available. Guard rails and pig brooders were removed and panels were used to adjust the pens to the proper size. Space allowances were of unencumbered floor space and were used for sleeping, standing, walking, defecating, etc.

A 16% protein ration [4] was fed throughout the experiment in small self-feeders with two feeding openings each. The space occupied by the self-feeders was not included in that allowed the hogs. They were allotted so that there was one opening for each three hogs. Thus in a pen of three, one opening was permanently closed, whereas in a pen of 12, two self-feeders were available. Each pen had one automatic drinking cup. The pens were cleaned once daily by washing down with water under pressure.

Sixty-three Duroc barrows and gilts were randomized into lot and treatment in each replicate. The initial weights were approximately 70 and 80 lb. respectively for the two replicates. At the conclusion of each replicate all hogs were probed for backfat thickness at the three standard sites with the Leanmeter. Two 24-hour activity watches [5] were made during each replicate by recording observations at 15-minute intervals.

During the summer of 1959 a field trial [6] was also run in Tehama County. There were three pens of 8, 16 and 32 hogs per pen, respectively, with space allotments per hog of 32, 16 and 9 sq. ft., respectively. Crossbred hogs were fed a commercially-mixed feed in self feeders where adjustments were made so that there were 4.0, 5.3 and 5.3 hogs per feeder opening, respectively. There was one automatic water fountain per pen. The hogs were housed in a feeding barn and outside pens with concrete floors. The wall was solid wood in the lower 3 feet with vertical, spaced lathes above. Half of the available floor space was in an outside pen with an eastern exposure. Feed and water were supplied in the

[1] This paper is one of a series from the cooperative project between the University of California and the United States Department of Agriculture.

[2] Departments of Animal Husbandry and Agricultural Engineering, respectively.

[3] Agricultural Engineers, Agricultural Engineering Research Division (ARS), U. S. Department of Agriculture.

[4] Barley—80, dehydrated alfalfa meal—5, soybean meal—3½, cottonseed meal—3½, meat and bone scraps—7½, salt—½. To each 100 lb. was added 10.2 gm. of zinc sulphate and 7.2 gm. of Quadrex-10, which contained 10,000 USP units of vitamin A and 1,250 USP units of vitamin D per gram.

[5] July 9–10, August 14–15, 1959, and February 12–13, 19–20, 1960.

[6] The authors wish to thank Frank Woodill, Vina, California, for his assistance and the use of his facilities and hogs in this trial. They also would like to express their appreciation for the help of Lin V. Maxwell, Farm Advisor, for his help and encouragement in completing the field experiment.

outer pen, and there were two spray nozzles along the fence directed out and over the hogs. These were turned on when the owner felt the weather justified it.

Hogs in the field trial averaged about 110 lb. at the start of the experiment and the experimental period was 49 days.

Statistical treatment was carried out by the analysis of variance. If the F value indicated significance at the 5% or 1% level, the Duncan (1955) multiple range test was used to identify the differences responsible for significance.

Results and Discussion

The results, based on two replicates at the University barn, are given in table 1. Analysis of variance for gains classified by square footage allotment showed statistically significant differences in trials 1 and 2. The combined results are also given in the table. Hogs with 20 sq. ft. each gained weight more rapidly than those with only 5 or 10 sq. ft. Number of hogs per pen apparently had no effect on gain. Live backfat probes with the Leanmeter showed no significant difference in fatness, either by actual probe or correction to a standard weight.

Space allotment had no significant effect on daily feed consumption (table 1), but the number of hogs per group did influence feed consumption. Statistical treatment indicated that hogs in groups of three consumed more feed than those in groups of 6 and 12.

Feed per unit of gain had a significant relationship (table 1) to both space allotment and size of group. The former apparently was caused by increase in weight, while the latter was related to feed consumption. Within the limits of this experiment, increased feed utilization was associated with increased space allotment and increased group size.

In the field trial it was not possible to vary both the size of the pen and the group. In the largest group of hogs with only 9 sq. ft. each, the feeder was found empty on three occasions. Feed consumption would be influenced and therefore gain; but probably not as great as indicated in table 2. Otherwise, the results in table 2 confirm those of the two trials run at the University.

The temperatures and relative humidities at the University hog barn and the barn of the field trial are given in table 3. Performance did not differ significantly between the summer and winter trials at the University (table 1).

Even with daily cleaning the pens allowing 5 sq. feet per animal were extremely dirty at the end of 24 hours. The drinking cups in these pens (open-type cup, no lid) almost invariably had dung in them within a few hours after cleaning. In the 10- and 20-sq. ft. pens, one or two distinct areas tended to be used for dunging, and the remainder of the pen remained relatively dry for resting and sleeping, even in the winter (trial 2). This was not possible in the 5-sq. ft. pens. In the winter trial, pens tended to be more damp. The pens used for the University trials had a slope of 3/16 in. per ft. which is less than now recommended and poor for

TABLE 1. SWINE PERFORMANCE AT THREE DIFFERENT SPACE ALLOTMENTS AND TWO REPLICATES (UNIVERSITY HOG BARN)

Item	Trial 1			Trial 2			Two trials combined		
	Gain	Av. daily feed	Feed per unit gain	Gain	Av. daily feed	Feed per unit gain	Gain	Av. daily feed	Feed per unit gain
Allotment, sq. ft. per hog	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
5	89.0	5.23	4.05	89.1	5.46	4.13	89.1	5.34	4.09[c]
10	92.4	5.17	3.89	93.4	5.29	3.84	92.9	5.23	3.86
20	96.9	5.22	3.83	100.1	5.22	3.54	98.5[a]	5.22	3.69
Number hogs per pen									
3	92.2	5.71	4.33	96.4	5.61	3.97	94.3	5.66[b]	4.15[d]
6	95.3	5.08	3.74	92.1	5.18	3.83	93.7	5.13	3.79
12	91.6	4.83	3.70	94.7	5.17	3.72	93.1	5.00	3.71
Replicate									
1	..	..	..	..	..	..	92.7	5.20	3.92
2	..	..	..	..	..	..	94.2	5.32	3.84

[a] Difference in gain from pigs with 5 or 10 sq. ft. statistically highly significant ($P<0.01$).
[b] Difference in feed consumption from groups of 12 pigs statistically highly significant, and from groups of 6 statistically significant ($P<0.05$).
[c] Difference in feed conversion from pigs with 20 sq. ft. statistically significant.
[d] Difference in feed conversion from groups of 6 and 12 pigs statistically significant.

TABLE 2. SWINE PERFORMANCE AT DIFFERENT SPACE ALLOTMENTS (FIELD TRIAL)
(Experimental period, 49 days)

Lot number	1	2	3
Hogs per lot	8	16	32
Sq. ft. per hog	32	16	9
Total gain, lb.	63.9	60.4	53.2[a]
Av. daily feed, lb.	5.11	4.77	4.53[b]
Feed per unit gain, lb.	3.92	3.87	4.17

[a] Difference in gain from lots 1 and 2 statistically significant ($P<0.05$).
[b] Lot 3 ran out of feed three times (see text).

washdown cleaning. As the lots with 5 sq. ft. per hog approached market weight, the hogs were packed tightly together in the pen especially in the lot of three pigs.

Two 24-hour activity checks were completed in each replicate in the University trials. Observations were made and recorded at 15-minute intervals. The data are reported as percentage of time spent in a particular activity assuming that the observation made at 15 minutes is representative of what the pigs were doing during a particular 15-minute period. The overall activity records are given in table 4. Space allotment per hog and number of hogs per pen both influenced the activity of the pigs. The general conclusion seems to be that groups with higher feed utilization tended to spend more time "sleeping and resting" and less time "standing or walking" and possibly "eating". Comparison of tables 1 and 4 indicates that hogs spending more time eating do not necessarily eat more feed. The correlation coefficient ($r=0.24$) between the percentage of time spent eating and average daily feed consumption is not statistically significant.

This study indicates that, within the limits of this experiment, increasing the space available per pig from 5 to 20 sq. ft. will increase weight gain and feed utilization about 10%. Increasing the number of pigs per group from 3 to 12 increased feed utilization by about 10%. These changes are not large enough to allow a blanket recommendation on space allowance. The most economical recommendation will depend upon the cost of additional pen space in relation to the cost of feed. It would appear important to extend this study to larger, commercial-sized groups of hogs.

TABLE 3. AMBIENT AIR TEMPERATURES AND RELATIVE HUMIDITIES IN THE THREE TRIALS

	University trials		Field trial[c]
	1[a]	2[b]	
Temperature, ° F.[d]			
Av. maximum	92.3	59.1	101.8
Av. mean	76.6	55.2	86.1
Av. minimum	64.6	51.0	72.2
Relative humidity, %[d]			
Av. maximum	71.8	81.1	41.8
Av. mean	51.7	73.4	32.3
Av. minimum	29.0	63.7	23.5

[a] June 15 to August 24, 1959.
[b] December 21, 1959 to February 27, 1960.
[c] June 30 to August 18, 1959.
[d] Recorded inside barns.

Summary

Two replicates of a 3 x 3 factorially-designed experiment involving 126 hogs are reported where space allotments of 5, 10 and 20 sq. ft. per hog and 3, 6 and 12 hogs per pen were compared. Hogs were self-fed in confinement in a large farrowing barn from 70 to 80 lb. to approximate market weight, and pens were cleaned by daily washdown.

Statistically significant differences in rate of gain and feed conversion in favor of the greater space allowance per hog and in lowered feed consumption and feed conversion in favor of pens with more hogs were found. Live backfat probes at the conclusion of each replicate failed to demonstrate detectable differences in fatness due to any treatment. Activity checks indicated that the pigs with greater feed conversion tended to spend more time sleeping or resting and less time stand-

TABLE 4. ACTIVITY OBSERVATIONS (UNIVERSITY HOG BARN)
(Values expressed as percentage of total time)

	Percent time spent[a]		
	Eating	Sleeping or resting	Standing or walking
Space allotment, sq. ft. per hog			
5	15.2	74.5	9.6
10	14.5	78.4	6.5
20	13.1[b]	81.0[c]	5.2[d]
Number of hogs per pen			
3	14.3	76.8	8.1
6	14.1	77.7	7.6
12	14.4	79.3	5.6[e]
Replicate			
1	14.5	78.8	5.7
2	15.2	77.7	6.0
3	14.0	77.2	8.5
4	13.2[f]	78.0	8.3

[a] Percent of hogs observed performing activity. Observations at 15-minute intervals for four 24-hour periods.
[b] Difference from 10 sq. ft. statistically significant ($P<0.05$) and 5 sq. ft. statistically highly significant ($P<0.01$).
[c] Difference from 5 sq. ft. statistically highly significant.
[d] Difference from 5 sq. ft. statistically significant.
[e] Difference from 3 and 6 pigs/pen statistically significant.
[f] Difference from replicates 1 and 2 statistically significant.

ing or walking. Time spent eating was not necessarily related to the amount of feed actually consumed.

A field trial is reported comparing 9, 16 and 32 sq. ft. per pig which confirmed the above results in that pigs with more space tended to gain weight faster with greater feed conversion.

Literature Cited

Bond, T. E. and G. M. Peterson. 1958. Hog houses. U. S. Department of Agriculture Misc. Pub. 744, pp. 4–5.

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics 11:1.

Noland, P. R., K. W. Scott and C. A. Baugus. 1959. In confinement feeding of pigs—space needs and feeder arrangement. Arkansas Farm Res. 8:8.

EFFECT OF PROTEIN SOURCE, AUTOCLAVING, AND LYSINE SUPPLEMENTATION ON GOSSYPOL TOXICITY [1]

A. J. Clawson, F. H. Smith, J. C. Osborne and E. R. Barrick [2]

North Carolina Agricultural Experiment Station, Raleigh

THE literature describing the effect of heat on the nutritive value of proteins has been summarized by Hayward *et al.* (1936). In general, casein and meat proteins are adversely affected while soy and other bean proteins are improved by moderate heat treatment. Osborne and Mendel (1917) and Gallup (1928) reported that excessive steaming or autoclaving of cottonseed or commercial cottonseed meals damaged the protein. Edgerton and Morris (1912), Dowell and Menaul (1923), Gallup (1928) and Robison (1934) have also shown that autoclaving commercial cottonseed meals reduces their toxicity. In many of the early cottonseed meal studies the results of heat damage were confounded by the presence of gossypol. Olcott and Fontaine (1941) used gossypol-free cottonseed meats and showed a graded reduction in the nutritive value of cottonseed protein as a result of autoclaving for different periods of time.

Lyman *et al.* (1953) showed that the availability of the amino acid, lysine was lowered as the total gossypol content of the meal increased. Olcott and Fontaine (1941) were able to show only a slight growth response in rats from lysine supplementation of autoclaved cottonseed meal. Whereas, Miner *et al.* (1955) obtained a significant growth response from supplementing a corn-cottonseed meal diet for swine with L-lysine.

The objectives of this study were to evaluate: (1) the effects of protein source and heat treatment on gossypol toxicity, and (2) the efficacy of the free amino acid L-lysine in preventing or overcoming the growth depression and toxic effects of free gossypol.

Method and Procedure

Experiment 1. A preliminary study was conducted to obtain information on the effect of protein source (cottonseed meal vs. soybean meal) and autoclaving of the protein in rations containing graded levels of added free gossypol, for growing pigs. The cottonseed meal (50% protein aniline treated) and soybean meal (50% protein) were autoclaved for 30 minutes and 2 hours, respectively, at 17 lb. of pressure at 245° F. for the first 90 lb. of feed consumed per pig. Since this produced no observable difference in gain between pigs fed autoclaved and non-autoclaved meals, the autoclaving time was increased to 45 minutes and 3 hours. The cottonseed meal was autoclaved for a shorter time because it was known that heat damaged cottonseed protein more than soybean protein.

The meals were autoclaved, 100 lb. at a time, in stainless steel trays. Twenty pounds of meal was spread, about 4 in. deep in each tray. One liter of water was added to each tray and thoroughly mixed with the meal in Experiment 2, but water was not added before autoclaving the meal used in Experiment 1. After autoclaving the meal was removed from the trays and spread out to cool and dry at room temperature. The autoclaved meal was not stored but was mixed into the respective rations within 24 hours.

The cottonseed meats used as a source of free gossypol were not autoclaved. The meats were taken from the flaking rolls of a commercial mill prior to cooking and pressing. Therefore, the bound gossypol content of the meats was low. Sewell (1943) and Lyman *et al.* (1944) have shown that heating in the presence of moisture is necessary for the conversion of free gossypol to the bound form. After screening to remove most of the hulls, a sample was analyzed and found to contain 1% of free gossypol. Cottonseed meats obtained in a similar manner have been shown in this laboratory to contain approximately

[1] Approved for publication as Paper No. 1280 in the Journal Series of North Carolina Agricultural Experiment Station.

[2] The authors acknowledge the assistance of the National Cottonseed Products Association, Inc., Dallas, Texas for grants-in-aid; Buckeye Cotton Oil Division of the Buckeye Cellulose Corporation, Cincinnati, Ohio for furnishing degossypolized cottonseed meal; U. S. Department of Agriculture, Southern Regional Research Laboratory, for special analysis of the meals; Buckeye Cotton Oil Co., Raleigh, North Carolina for supplying the cottonseed meats; Chas. Pfizer and Co., Inc., Terre Haute, Indiana for supplying the lysine; and to C. M. Lyman, Texas Agricultural Experiment Station for lysine analysis.

0.3% bound gossypol. The experimental rations contained 75.5% ground yellow corn, 16.5% cottonseed meal or soybean meal, 5.0% dehydrated alfalfa meal, 1.0% defluorinated phosphate, 1.0% lime, 0.5% trace mineral salt and 0.5% vitamin premix. The ingredients in the vitamin premix were the same as used in Experiment 2 and are shown in table 1. The cottonseed meats used as a source of free gossypol were added to the rations at graded levels.

Thirty-five Duroc and crossbred pigs averaging 44 lb. were randomly allotted from litter-mate groups to ration treatments as indicated in table 2. The pigs were fed individually in 4 x 9 sq. ft. indoor pens with concrete floors. Each pen contained a self-feeder and an automatic watering cup. The pens were cleaned daily and no bedding was used. Weights and feed consumption data were recorded at biweekly intervals. Animals that died were removed to a Veterinary Research Laboratory for observation of gross macroscopic lesions. Tissues were taken for histological studies from the heart, lungs, liver, spleen, kidney, adrenal, stomach, small and large intestines.

Experiment 2. The second experiment was conducted to obtain additional information on the effect of autoclaving cottonseed protein in relation to gossypol toxicity and to study the effectiveness of lysine supplementation in overcoming gossypol toxicity and improving growth rate of pigs fed heat damaged cottonseed meal.

Thirty-six pigs weaned at 7 weeks of age and averaging 32 lb. initially were randomly allotted from breeding groups to six ration treatments. Management, housing and autopsies were handled as in Experiment 1. The experimental treatments were as follow: 1. Control (corn-degossypolized cottonseed meal), 2. Control plus 0.02% free gossypol, 3. Control plus 0.03% free gossypol, 4. Same as No. 3 plus 0.2% L-lysine, 5. Same as No. 2 using autoclaved cottonseed meal, and 6. Same as No. 5 plus 0.2% L-lysine. The meal used in this study contained less than 0.04% free gossypol and 44% protein. In its manufacture an aromatic amine was used to combine with and inactivate free gossypol. The non-autoclaved cottonseed meats used as a source of free gossypol contained 0.97% free gossypol and 36% protein. Composition of the rations fed in Experiment 2 are presented in table 1.

Results and Discussion

Experiment 1. Solubility of the nitrogen in the cottonseed and soybean meal proteins, as determined by the method of Lyman *et al.* (1953), was reduced by autoclaving. Nitrogen solubility was reduced from 85% to 33% as a result of autoclaving soybean meal for 2 hours. Solubility of nitrogen in the cottonseed protein was reduced from 87% to 79% by autoclaving for 30 minutes. Nitrogen solubility was not determined for meals autoclaved for longer periods of time.

Rate of gain of pigs fed the autoclaved meals was not significantly reduced; therefore, the data for autoclaving was pooled and shown only by protein source in table 2. Apparently dry soybean meal can withstand severe autoclaving without greatly reducing protein quality as measured by growth rate of pigs. The cottonseed meal used in Experiment 1 was apparently of high quality and the short autoclaving time used was not adequate to reduce pig gains. The addition of

TABLE 1. RATIONS USED TO STUDY THE EFFECT OF AUTOCLAVING AND ADDED LYSINE ON GOSSYPOL TOXICITY IN CORN-COTTONSEED MEAL RATIONS[a]
(Experiment 2)

Ration no.	1	2	3	4	5	6
Ground corn	75	75	75	75	75	75
Cottonseed meal[b]	16	14	13	12.8	..	..
Autoclaved CSM[c]	..	..	..	..	14	13.8
Supplement[d]	9	9	9	9	9	9
Cottonseed meats[e]	..	2	3	3	2	2
L-lysine monhydrochloride	..	..	..	0.2	..	0.2

[a] Calculated protein 14%, calcium 0.79%, phosphorus 0.51%.
[b] Supplied by Buckeye Cotton Oil Division of the Buckeye Cellulose Corporation, Cincinnati, Ohio.
[c] The cottonseed meal used in rations 5 and 6 was autoclaved for three hours at 17 pounds of steam pressure and 245° F.
[d] The percentage composition of the remainder of the ration was as follows: yellow grease 5.0, dehydrated alfalfa meal 1.0, defluorinated phosphate 1.0, limestone 1.0, vitamin antibiotic mix 0.5. The vitamins and antibiotic supplement contained vitamin A 100,000 U.S.P. units, vitamin D 100,000 U.S.P. units, vitamin E 100 I.U., riboflavin 300 mg., niacin 2000 mg., pantothenic acid 800 mg., choline 10,000 mg., B_{12} 1.0 mg., and chlortetracycline hydrochloride 1 gm. per pound.
[e] Epsilon amino lysine as a percent of the protein as follows: degossypolized cottonseed meal 4.1, autoclaved degossypolized cottonseed meal 2.8, and cottonseed meats 4.0.

TABLE 2. THE EFFECT OF PROTEIN SOURCE AND FREE GOSSYPOL LEVEL IN THE RATION ON PERFORMANCE OF PIGS[a]
(Experiment 1)

Protein source	Gossypol level[b]	Ave. initial wt.	Av. no. days on trial	Av. final wt.	Av. daily gain	Av. daily feed	Feed per lb. gain	No. deaths
Soybean meal								
	0.000	40	97	195	1.60	6.47	4.05	..
	0.012	43	91	210	1.74	6.52	3.75	..
	0.024	47	89	206	1.78	6.52	3.66	..
	0.036	46	72	137	1.27	4.84	3.98	2[c]
	0.048	42	73	140	1.32	5.04	3.85	2[d]
Cottonseed meal								
	0.006	43	94	204	1.70	6.34	3.73	..
	0.012	42	94	198	1.65	6.07	3.67	..
	0.018	41	100	210	1.69	6.29	3.72	..
	0.024	43	99	191	1.51	5.92	3.91	..
	0.030	45	78	152	1.39	5.58	4.01	2[e]

[a] Four and three pigs per treatment on cottonseed meal and soybean meal respectively.
[b] Includes residual free gossypol contained in the cottonseed meal plus that which was added.
[c] Died after 61 and 67 days on trial.
[d] One pig died after 48 days on trial, one pig grew rapidly and died suddenly from acute toxicity after 62 days on trial.
[e] Died after 45 and 67 days on trial, the two remaining pigs had edematus lungs when slaughtered.

moisture to the meals before autoclaving would probably have resulted in more heat damage to the meals.

Levels of free gossypol up to .024% of the diet, did not significantly depress growth or cause toxicity when added to either corn-soybean meal or corn-cottonseed meal rations (table 2). A free gossypol level of 0.03% of the diet containing protein from cottonseed meal reduced growth, though not statistically significant, and resulted in death of two of four pigs fed this ration. Toxicity and death resulted when 0.036% and 0.048% free gossypol was fed in corn-soybean meal rations. In this study it appears that there was no difference in toxicity of gossypol when fed at comparable levels in diets containing soybean meal or cottonseed meal. In feeding trials with pigs Robison (1934) showed that ration ingredients other than cottonseed meal had an influence on gossypol toxicity. Reports, by Holley *et al.* (1955), Wallace *et al.* (1955) and Sewell *et al.* (1957), have all shown that mixtures of cottonseed meal with other protein supplement sources improve the performance of pigs when compared with pigs fed cottonseed meal as the only source of protein.

Experiment 2. Performance data on the pigs used in this study are presented in table 3. The pigs fed ration 1 (corn and degossypolized cottonseed meal with no added gossypol) did not gain at an optimum rate (1.26 lb., A.D.G.). This ration was calculated, on the basis of composition of the ingredients, to contain 0.8% lysine.

Increasing the level of gossypol in the diet containing degossypolized cottonseed meal to 0.026% by the addition of cottonseed meats (ration 2) resulted in death of two of six pigs, although there was no statistical evidence that rate of gain or feed intake (calculated on a pig-day basis) was affected. Some pigs fed rations containing gossypol grew rapidly and suddenly died from acute toxicity without showing apparent outward symptoms; whereas, other pigs developed symptoms of toxicity (labored breathing and inanition). The pigs in a chronic state of toxicity grew slowly but often made a partial recovery before finally succumbing to the toxic factor(s). This may make rate of gain a rather poor criterion for evaluation in a gossypol toxicity study.

Feed intake and growth rate of pigs fed rations 3 and 4 which contained 0.036% of free gossypol were significantly ($P<0.05$) depressed when compared with the performance of pigs fed the control ration. Four of six pigs fed ration 3 died from gossypol toxicity and the remaining two pigs showed symptoms of toxicity (labored breathing). The addition of 0.2% L-lysine to this high gossypol ration (treatment 4) did not improve growth rate or alleviate the gossypol toxicity; in fact, daily feed intake and rate of gain were both slightly, though non-significantly, depressed in comparing treatment 3 vs. 4. 100% mortality resulted when ration 4 was fed. A higher level of added lysine might have overcome the toxic effects of the gossypol in ration 4. Lyman *et al.* (1959) showed that when gossypol combines with

TABLE 3. THE EFFECT OF AUTOCLAVING AND LYSINE SUPPLEMENTATION ON GOSSYPOL TOXICITY[a]
(Experiment 2)

	Degossypolized CSM				Autoclaved degoss. CSM	
Added L-lysine %	0	0	0	0.2	0	0.2
Free gossypol %[b]	0.006	0.026	0.036	0.036	0.026	0.026
Av. initial wt., lb.	32	33	32	31	32	32
Av. final wt., lb.[c]	183	156	112	83	80	162
No. deaths	..	two	four[e]	six	one	..
Av. daily gain, lb.[d]	1.26	1.26	0.87	0.69	0.38	1.09
Av. total feed per pig, lb.	492	386	283	166	249	457
Av. daily feed, lb.	4.08	3.97	3.06	2.19	1.99	3.84
Feed per cwt. gain, lb.	325	314	353	317	522	353
Free gossypol consumed						
per pig, gm.	..	35	39	23	23	41
per cwt. of pig, gm.	..	22	34	27	28	26
per cwt. per day, gm.	..	0.23	0.37	0.36	0.23	0.22

[a] Performance data, six pigs per treatment (125 day trial).
[b] Includes residual free gossypol contained in the meal as well as that added from cottonseed meats.
[c] Includes weight at previous weigh day prior to death.
[d] Calculated on a pig day basis.
[e] Remaining two pigs were posted and had lesions of gossypol poisoning.

cottonseed protein, the reaction is with the free epsilon-amino group of lysine. Baliga and Lyman (1957) showed that as the gossypol-protein complex was formed, lysine availability was decreased from 83 to 49%. Gossypol-protein complexes, prepared by the use of pure gossypol and purified protein, have been reported by Castillon and Altschul (1950) and Baliga and Lyman (1957). Lysine-gossypol compounds have been prepared and fed to rats (Chang *et al.*, 1955) and to chicks (Couch *et al.*, 1955). In these studies essentially all of the lysine as well as the gossypol was recovered in the feces.

The effect of lysine supplementation on gossypol tolerance was studied by Earle (1959). A basal corn-cottonseed meal diet containing 13% protein and 0.011% free gossypol was fatal to two out of seven pigs. Whereas, there was no evidence of toxicity at any level of added lysine tested, even though the daily intake of free gossypol per kg. of body weight was slightly higher in these pigs. In contrast, Couch *et al.* (1955) observed that the addition of lysine to cerelose-cottonseed meal rations for chicks increased rate of growth at all levels of dietary gossypol but did not change the gossypol tolerance level. Wallace *et al.* (1955) reported a variable response from the addition of DL-lysine to corn - low gossypol cottonseed meal rations for pigs. In one experiment the addition of 0.8% lysine to the ration did improve gains. In the studies reported by Wallace *et al.* (1955) the addition of iron sulfate resulted in a favorable growth response in four of six comparisons. These authors postulated that since iron has been shown to be an effective antidote for gossypol poisoning, the presence of gossypol may have been a limiting factor on growth, even though no physical symptoms of toxicity were observed.

Autoclaved degossypolized cottonseed meal was used as the source of protein in rations 5 and 6 which were formulated to contain 0.026% free gossypol. The protein of the non-autoclaved cottonseed meal contained 4.1% lysine; after autoclaving, the lysine content was reduced to 2.8%. Feed intake and growth rate of pigs fed diet 5 containing the autoclaved cottonseed meal were significantly ($P<0.01$) depressed when compared to pigs fed ration 1. One death resulted in pigs fed this ration. Addition of 0.2% of L-lysine (ration 6) making a calculated lysine content of 0.8% resulted in a significant improvement in feed intake as compared to pigs fed ration 5 and a growth rate almost equal to that of the control pigs (1.09 lb. per day). No deaths resulted in pigs fed this ration. The addition of 0.2% of L-lysine appears to have prevented manifestation of fatal gossypol toxicity. Four pigs of this group reached market weight. The other two pigs gained at a slow rate. A higher level of added lysine might have completely overcome the growth depression which resulted when the autoclaved meal was fed. Ingram *et al.* (1950), Milligan and Bird (1951), Kuiken (1952) and Sure (1953) have shown that cystine and methionine are also

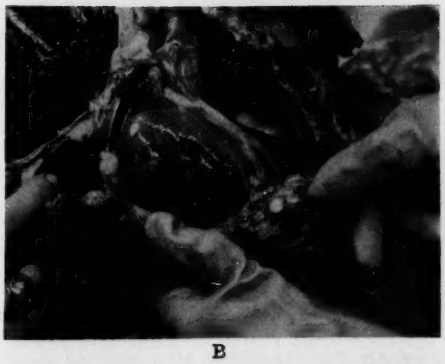
heat-labile amino acids or that their availability is altered by heat treatment. The lowered availability of cystine and of methionine may be another reason for the inability of lysine to completely overcome the effect of autoclaving.

Bound gossypol or other factors in the autoclaved meal and in the added cottonseed meats may also be limiting performance. Baliga and Lyman (1957) reported that the removal of bound gossypol from cottonseed meal increased the nutritional value of the protein for chicks. Smith *et al.* (1958) lowered the growth response of weanling rats significantly by binding gossypol on cottonseed, soybean or peanut protein.

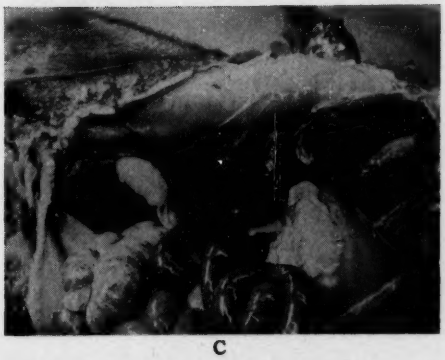
Pulmonary edema, hydrothorax and ascites (figure 1) were the most conspicuous gross pathology features in pigs that died from gossypol toxicity in this study. Other gross lesions were also encountered. Classical histopathological changes of alveolar and interlobular edema and congestion, severe centrolobular hepatic degeneration, and myocardial degeneration and/or hypertrophy were encountered. The gross microscopic changes encountered in this study were very similar to the detailed description of gossypol poisoning published by Smith (1957).

Grams of free gossypol consumed per pig (table 3) or per unit weight were not closely associated with toxicity.

A



B



C

Figure 1. A. Pulmonary edema; B. Hydrothorax and myocardial hypertrophy; C. Ascites.

Summary

Graded levels of free gossypol from cottonseed meats were added to corn-degossypolized cottonseed meal and corn-soybean meal diets for growing pigs. Solubility of the soybean nitrogen was reduced from 85% to 35% by autoclaving for 2 hours at 17 lb. of steam pressure. Solubility of cottonseed nitrogen was reduced from 87.4% to 79% by autoclaving for 30 minutes. Rate of gain of pigs fed the autoclaved meals was not significantly reduced. Addition of free gossypol at the levels of 0.03% and 0.036%, respectively, to both corn-cottonseed meal and corn-soybean meal diets resulted in depressed growth and death of the pigs.

In a second study autoclaving degossypolized cottonseed meal for 3 hours at 17 lb. of pressure reduced growth of pigs from 1.26 lb. to 0.38 lb. per day. Addition of 0.2% of L-lysine resulted in growth almost equal to that of pigs receiving non-autoclaved meal (1.09 lb. per day). This was in the presence of 0.026% of added free gossypol. When the free gossypol level was increased to 0.036% of the diet, growth rate was reduced and four of six pigs died from gossypol toxicity. There was no evidence that addition of 0.2% of

L-lysine to this high gossypol ration improved growth or reduced death losses.

Literature Cited

Baliga, B. P. and C. M. Lyman. 1957. Preliminary report of the nutritional significance of bound gossypol in cottonseed meal. J. Am. Oil Chem. 34:21.

Castillon, L. E. and A. M. Altschul. 1950. Preparation of water-soluble combination products of gossypol and their toxicity to aquarium fish. Proc. Soc. Exp. Biol. Med. 74:623.

Chang, W. Y., J. R. Couch, C. M. Lyman, W. L. Hunter, Van P. Entwistle, W. C. Green, A. B. Watts, C. W. Pope, C. A. Cabell and I. P. Earle. 1955. The nutritional value of prepress-solvent cottonseed meals. J. Am. Oil Chem. Soc. 32:103.

Couch, J. R., W. Y. Chang and C. M. Lyman. 1955. The effect of free gossypol on chick growth. Poul. Sci. 34:178.

Dowell, C. T. and P. Menaul. 1923. Effect of autoclaving upon the toxicity of cottonseed meal. J. Agr. Res. 26:9.

Earle, I. P. 1959. Use of cottonseed meal in swine studies. Proc. 5th Conf. of Processing as Related to Nutritive Value of Cottonseed Meal, p. 52.

Edgerton, C. W. and Harry Morris. 1912. Some studies on cottonseed meal poisoning. La. Agr. Exp. Sta. Bul. 134.

Gallup, W. D. 1928. The digestibility of the proteins of some cottonseed products. J. Biol. Chem. 76:43.

Haywood, J. W., H. Steenbock and G. Bohstedt. 1936. The effect of heat as used in the extraction of soybean oil upon the soybean oil meal. J. Nutr. 11:219.

Holley, K. T., W. S. Harms and R. W. Stockew. 1955. Cottonseed meal in swine and rabbit rations. Ga. Agr. Exp. Sta. Mimeo. N. S. 12.

Ingram, G. R., W. W. Cravens and C. A. Elvehjem. 1950. Evaluating cottonseed meal protein for chick growth by enzymatic release of amino acids. Poul. Sci. 29:590.

Kuiken, K. A. 1952. Availability of essential amino acids in cottonseed meal. J. Nutr. 46:13.

Lyman, C. M., B. P. Baliga and M. W. Slay. 1959. Reactions of protein with gossypol. Arch. Biochem. 84:486.

Lyman, C. M., Wan Yuin Chang and J. R. Couch. 1953. Evaluation of protein quality in cottonseed meal by chick growth and by a chemical index method. J. Nutr. 49:679.

Lyman, C. M., B. R. Holland and F. Hale. 1944. Processing cottonseed meal and manufacturing methods for eliminating toxic qualities. Ind. Eng. Chem. 36:188.

Milligan, J. L. and H. R. Bird. 1951. Effect of processing variants on the nutritive value of cottonseed meal for chicks. Poul. Sci. 30:651.

Miner, J. J., W. B. Clower, P. R. Noland and E. L. Stephenson. 1955. Amino acid supplementation of a corn-cottonseed meal diet for growing-fattening swine. J. Animal Sci. 14:24.

Olcott, H. S. and T. D. Fontaine. 1941. The effect of autoclaving on the nutritive value of cottonseed meal. J. Nutr. 22:431.

Osborne, T. B. and L. B. Mendel. 1917. Adverse effect of heat on cottonseed pellets. J. Biol. Chem. 29:289.

Robison, W. L. 1934. Cottonseed meal for pigs. Ohio Agr. Exp. Sta. Bul. 534.

Sewell, R. F., B. C. Keen and J. L. Carmon. 1957. The value of various blends of soybean oil meal, peanut oil meal, and degossypolized cottonseed oil meal as protein supplements in swine rations. J. Animal Sci. 16:357.

Sewell, W. E. 1943. Detoxification of cottonseed meal for hogs. Ala. Polytech. Inst., Agr. Exp. Sta. Bul. 259.

Smith, F. H., C. T. Young, and F. W. Sherwood. 1958. Effect of bound gossypol on the growth-promoting properties of cottonseed, soybean and peanut meals. J. Nutr. 66:393.

Smith, H. A. 1957. The pathology of gossypol poisoning. Am. J. Path. 33:353.

Sure, Barnett. 1953. Influence of processing on the protein value of cottonseed meals. J. Agr. Food Chem. 1:82.

Wallace, H. D., T. J. Cunha and G. E. Combs. 1955. Low-gossypol cottonseed meal as a source of protein for swine. Fla. Agr. Exp. Sta. Bul. 566.

INFLUENCE OF DIETARY SUPPLEMENTS ON GROWTH OF BEEF CALVES ON SEMI-DESERT RANGE [1]

V. R. BOHMAN,[2] H. MELENDY [3] AND M. A. WADE [4]

University of Nevada, Reno

THE majority of cattle in Nevada are produced in the northern half of the state under a two-phase system. That is, cattle graze on federal range during the summer and are fed harvested forage on private meadows during the winter period. In contrast, cattle in the southern part of the state usually remain on the range for the entire year. During drouth periods, which are frequent, production is severely restricted. Even during better years, production only approaches that found in the rest of the state.

The purpose of this study was to determine the weight gains and certain blood constituents of beef calves on semi-desert ranges. A second purpose was to determine the effect of dietary supplements on these items.

Experimental Procedure

Each year during a 4-year period, weanling Hereford calves were maintained on semi-desert range in Southern Nevada. This range was estimated to have a vegetative cover of 95% browse and 5% grass. Thirty-two animals were used in each of the first 2 years and 48 each year thereafter. These cattle received one of the following experimental supplements in addition to the range forage: none (controls); 1 lb. barley; 1 lb. commercial protein supplement, soybean or cottonseed meal; and 3 lb. of alfalfa pellets daily during the winter period. Soybean meal was used as the source of commercial protein in 2 of the 4 years and cottonseed meal in the other 2. In addition, one-half of the cattle in each group were fed 8 gm. of phosphorus daily in the form of bone meal or bone meal and other supplements when fed. When phosphorus only constituted the supplement the bone meal was mixed with a limited amount of wheat bran as a carrier and pelleted. In those groups that received supplemental phosphorus, the amount of bone meal was adjusted with the other supplement (energy or protein) so that each animal received the same amount of this element. The average composition of the supplements is given in table 1.

All cattle ranged as a group except during the daily feeding of supplements. Since the study was conducted on open (non-fenced) range, the herd was kept together by providing water at the corral area. In order to avoid overgrazing in a particular area, portable facilities were devised (figure 1). Corrals were constructed of snow-fence and steel posts. Two feeding lanes were constructed so that they could be sub-divided into five parts each, allowing 10 animals to be fed supplements individually at one time. A squeeze chute, mounted on a portable scale, was used for restraining the animals when individual weights and blood samples were obtained. These facilities were moved to a new location every 2 to 8 weeks depending on the available feed and weather conditions. After intervals of 1 year or longer, the area might be grazed a second time. Animals were offered supplements as they came to the corral area for water. Animals that failed to appear at one feeding received a double portion of supplement the following day. On the average, cattle that received supplements were fed 65 days out of each 100 days; the controls watered 55 days each 100 days. Cattle were observed grazing up to 8 miles from the

TABLE 1. COMPOSITION OF FEED SUPPLEMENTS

Feed	Composition of dry matter in percent			
	Protein	Crude fiber	P	mg./lb. carotene
Barley	14.2	6.5	0.44	..
Barley + P[a]	13.4	6.6	1.72	..
Alfalfa	17.2	29.6	0.25	8.2
Alfalfa + P	16.5	27.4	0.71	7.8
Cottonseed meal	44.4	18.3	1.18	..
Cottonseed meal + P	39.8	17.6	1.72	..
Soybean meal	45.1	7.7	0.72	..
Soybean meal + P	42.7	7.3	1.82	..
Phosphorus pellet	15.5	14.6	3.41	..

[a] P=Added phosphorus.

[1] Supported in part by a grant from the Atomic Energy Commission and in cooperation with the Western Regional Project, W-34, Range Livestock Nutrition.

[2] Department of Animal Husbandry.

[3] Present address: Extension Service, University of California, Fresno, Calif.

[4] Present address: Phillips Petroleum Co., Arco, Idaho.

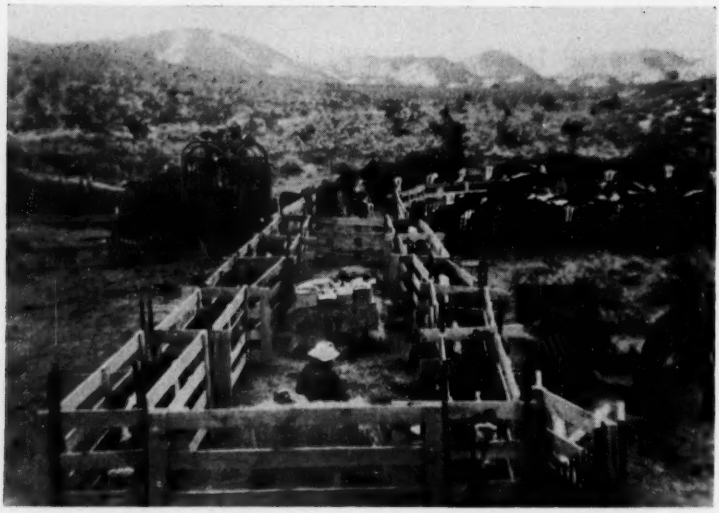


Figure 1. Portable corrals, feeding lanes, squeeze chutes and scale for individual feeding of range cattle.

corral area. Usually they remained within 4 miles of the facilities. Animals were identified by the use of large (1⅛" round) ear tags and hair dye.

Plasma phosphorus (Fiske and Subba-Row, 1925), vitamin A and carotene (Kimble, 1939) were determined. In addition, during the first three years, hemoglobin, total cells (Bohman and Wade, 1958) and calcium (Clark and Collip, 1925) were determined. The hematocrit was determined the fourth year only.

Results and Discussion

The growth data are given in tables 2 and 3. During the winter period both supplemental energy (barley) and protein (alfalfa, soybean or cottonseed meal) increased the rate of gain. Protein was more effective than energy as a supplement during this period. Contrary to other work (Bohman, 1955; Bohman and Torell, 1956; Bohman *et al.*, 1959) winter treatments had no significant effect on subsequent summer growth although a

TABLE 2. THE GROWTH OF WEANLING BEEF CALVES AS INFLUENCED BY DIETARY SUPPLEMENTS FOR FOUR YEARS[a]

	Winter supplements, daily				
Amount daily	None	Barley 1.0 lb.	SOM or CSM 1.0 lb.	Alfalfa 3.0 lb.	Total or average
No. of cattle	40	40	40	40	160
			Winter period (156 days)		
Initial weight, lb.	334	337	341	340	339
Daily gain, lb.	0.22[b]	0.34	0.51	0.52	0.40
			Summer period (190 days)		
Daily gain, lb.	1.21	1.15	1.14	1.18	1.17
			Entire year (346 days)		
Daily gain, lb.	0.79	0.82	0.86	0.88	0.84

[a] Average values.
[b] Figures that differ significantly are not joined by an underline.

TABLE 3. THE GROWTH OF WEANLING BEEF CALVES AS INFLUENCED BY PHOSPHORUS SUPPLEMENTS FOR FOUR YEARS[a]

	Phosphorus supplement		
	8.0 gm. daily	None	Average or total
No. of cattle	80	80	160
	Winter period (156 days)		
Initial weight, lb.	334	342	..
Daily gain, lb.	0.43	0.36	0.40
	Summer (190 days)		
Daily gain, lb.	1.21*	1.13	1.17
	Entire year (346 days)		
Daily gain, lb.	0.87**	0.80	0.84

[a] Average values.
*,** Statistically significant at $P<.05$ and $<.01$, respectively.

similar trend was obtained. It is possible that the basal feeding regimes (grazed forage vs. harvested hay) during the winter period may be responsible. Both groups (this study and others cited) grazed range forage during the summer. Phosphorus supplementation failed to increase the growth rate significantly during the winter period, although the cattle fed this supplement gained slightly more. During the summer, when only phosphorus supplements were fed, this nutrient increased the growth rate significantly. Winter protein and yearly phosphorus supplementation increased the growth rate of weanling calves approximately the same amount. No interaction among the factors was evident.

Growth of the calves during the winter period was quite consistent during different years. In 3 of the 4 years the average gain was 0.35 or 0.36 lb. daily. For the fourth year the average gain was 0.54 lb. However, during the summer the rate of gain was markedly different by years and ranged from 0.85 lb. to 1.32 lb. per day. The range area was declared a drouth-disaster area during the summer of 1956 when the smallest gains were observed. Yearly gains varied from 0.58 to 1.06 lb. daily. The relative effect of dietary treatments was similar for the various years studied. The greatest absolute difference between the control and supplemented groups was observed during those years when maximum growth was obtained.

The amount of hemoglobin, total cells, and percent red blood cells was highest at weaning in November and gradually decreased during the winter period until March. After March, the values increased once more. Winter supplements modified this relationship. The change in hemoglobin, total cells, and hematocrit during the winter is given in table 4. While these blood constituents generally decreased during the winter period, the change was not as great when the cattle received supplementary feed. Protein supplements were more effective in this regard than energy. Since protein from widely divergent sources produced a similar effect on growth and the cellular constituents of the blood, it is unlikely that some other component of the protein supplement i.e., mineral, etc., is responsible for this effect. The decline in these constituents for the control animals was greater than in a previous study (Bohman *et al.*, 1959) when grass hay alone was fed. Extra protein failed to arrest completely this decline although it did with a basal grass hay diet in a previous study.

The level of plasma phosphorus was affected by both phosphorus and other supplements. Phosphorus supplementation increased the level of plasma phosphorus immediately after feeding was initiated in the fall and the supplemented cattle had higher levels of plasma phosphorus each month throughout the year (figure 2). The differences were greatest during the winter period and the following fall. The levels of plasma phosphorus between the supplemented and control groups were least during the period of most active plant growth (early summer). Range plants contained the

TABLE 4. THE EFFECT OF FEED SUPPLEMENTS ON THE CHANGE IN CERTAIN BLOOD CONSTITUENTS DURING THE WINTER PERIOD

	Supplement				
Blood Constituent	None	Barley 1 lb.	Alfalfa 3 lbs.	CSM or SOM, 1 lb.	Av.
Hemoglobin, g./100ml (Nov. to May)	—1.6[a]	—0.7	—0.1	0.30	—0.5
Total cells, millions mm^3 (Nov. to May)	—1.85	—0.98	—0.67	—0.21	—0.93
Hematocrit, % rbc. (Nov. to Mar.)	—3.2	—1.8	—0.2	—0.9	—1.5

[a] Figures that differ significantly are not joined by an underline.

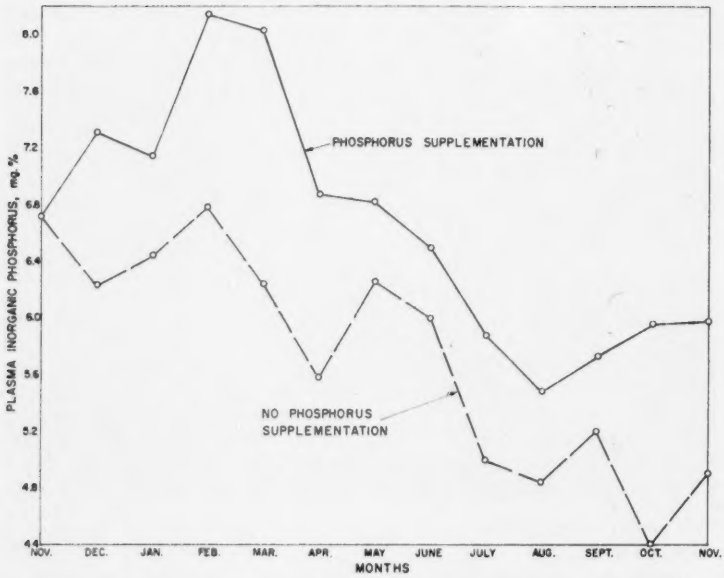


Figure 2. The effect of dietary phosphorus on plasma inorganic phosphorus in range beef cattle.

highest level of phosphorus during the same period (Bohman, unpublished data). Plasma phosphorus was least in the control group during October and highest during the winter months. These seasonal effects may be caused by two factors. First, the protein and barley supplements also contained some phosphorus and were fed to three-fourths of the phosphorus-control cattle during the winter period. An additional and perhaps more logical explanation is the normal decline in plasma phosphorus associated with the age and consequently, the development of the animal. Mature cattle have lower levels of plasma phosphorus than growing animals (Bohman, unpublished data; Marsh *et al.*, 1959). Davis (1959) reported that a plasma inorganic phosphorus level of 5–7 mg.% is normally adequate for young cattle and a low value was almost conclusively diagnostic of a deficiency situation. The cattle that did not receive phosphorus supplements had inorganic phosphorus levels less than 5 mg.% during most of the summer while those receiving phosphorus were above this level. The plasma inorganic phosphorus in these cattle supports the growth data.

Plasma calcium varied less than plasma phosphorus. It appeared to show slight seasonal trends. The lowest level (9.0 mg.%) occurred during March. It rose during April and May, and the highest level (10.3 mg.%) was present during June and August. During the fall the level gradually decreased to 9.4 mg.% in November. Dietary supplements had no effect on the level of plasma calcium. Marsh *et al.* (1959) found no seasonal variations or trends with plasma calcium with mature cows. Since these animals were nursing calves during part of this time, lactation may have masked any seasonal effect.

Plasma carotene concentrations showed marked seasonal variations as expected. The lowest levels occurred during January and February. Average levels for these months were 165 and 155 mcg/100 ml. plasma. Maximum levels were obtained during May. From a high level of 592 mcg/100 ml. plasma, the level of plasma carotene decreased gradually to 391 mcg/100 ml. plasma in November. Vitamin A showed a similar although less variable trend. Plasma vitamin A was far greater at all times than the amount required to prevent vitamin deficiency symptoms. The range of vitamin A is shown in table 5.

The effect of dietary supplements on plasma carotene and vitamin A is given in table 5. Plasma carotene of barley-supplemented calves was higher than the other treatments during the winter period after supplementa-

TABLE 5. PLASMA CAROTENE AND VITAMIN A AS MODIFIED BY DIETARY SUPPLEMENTS

Treatments		Barley	Controls	Alfalfa	Protein
Initial level—	Carotene	260	249	272	263
(November)	Vit. A.	39.0	37.1	38.8	40.1
Change in plasma—	Carotene	382[a]	367	310	265
(November to May)	Vit. A.	30.5	28.5	25.8	20.0
End of winter—	Carotene	642	616	582	528
(May)	Vit. A.	69.5	65.6	64.6	60.1
End of summer—	Carotene	404	367	390	394
(November)	Vit. A.	45.5	42.9	46.2	41.6

[a] Figures that differ significantly are not joined by an underline.

tion was initiated. In contrast, the plasma levels were lowest for the protein-supplemented groups. This difference was significant for each month from March through May. The control animals and the alfalfa-supplemented cattle were intermediate. During the summer when these supplements were not fed, this difference was not evident. Plasma vitamin A exhibited a similar effect at the end of the winter period.

Alfalfa, as a carotene source, had no apparent effect on the level of plasma carotene or vitamin A. The relative high level of vitamin A and carotene in the plasma of all cattle may have minimized this effect.

Summary

The growth of 160 weanling calves on semi-desert range during a period of 4 years was studied. Dietary supplements of phosphorus, energy (barley), protein (cottonseed meal, soybean meal and alfalfa) were fed to part of the animals in a 2 x 4 factorial-designed experiment. All cattle grazed the same range but were individually fed supplements in portable pens as they came in for water. During the winter all supplements except phosphorus increased the rate of gain above the control animals. Cattle fed protein supplements grew significantly faster than those fed the barley supplement. The rate of gain was equal for the protein-supplemented groups. During the summer, only phosphorus increased the rate of gain but for the entire year both phosphorus and winter protein supplements resulted in greater gains. Large yearly variatons in growth response were observed. Blood analyses were made periodically. The level of circulatory erythrocytes was greater when protein supplements were fed. Phosphorus supplements consistently increased the level of plasma phosphorus. Alfalfa, as a carotene source, had no effect on the level of plasma carotene or vitamin A. Cattle supplemented with barley had the highest level of plasma carotene; those supplemented with protein were least.

Literature Cited

Bohman, V. R. 1955. Compensatory growth of beef cattle: The effect of hay maturity. J. Animal Sci. 14:249.

Bohman, V. R. and C. Torell. 1956. Compensatory growth of beef cattle: The effect of protein supplements. J. Animal Sci. 15:1089.

Bohman, V. R. and M. A. Wade. 1958. The effect of certain feed additives on the tissues of fattening beef cattle. J. Animal Sci. 17:125.

Bohman, V. R., M. A. Wade and C. Torell. 1959. Effect of animal fat and protein supplements on range beef cattle. J. Animal Sci. 18:567.

Clark, E. P. and J. B. Collip. 1925. A study of the Tisdall method for the determination of blood serum calcium with a suggested modification. J. Biol. Chem. 63:461.

Davis, George K. 1959. Mineral deficiencies and mineral requirements of livestock. International Feed Symposia, Foreign Agr. Ser. USDA, Wash. D.C. p. 19.

Fiske, C. H. and Y. SubbaRow. 1925. The colorimetric determination of phosphorus. J. Biol. Chem. 66:375.

Kimble, M. S. 1939. Photocolorimetric determination of vitamin A and carotene in human plasma. J. Lab. Clin. Med. 24:1005.

Marsh, H., K. F. Swingle, R. R. Woodward, G. F. Payne, E. E. Frahm, L. H. Johnson and J. C. Hide. 1959. Nutrition of cattle on an eastern Montana range as related to weather, soil and forage. Mont. Agr. Exp. Sta. Bul. 549.

EFFECT OF ANTEMORTEM ADMINISTRATION OF ADRENALINE ON POSTMORTEM LAMB CARCASS CHARACTERISTICS [1]

H. B. Hedrick, J. B. Boillot, A. J. Dyer and H. D. Naumann

Missouri Agricultural Experiment Station, Columbia

COLOR of muscle in meat animals is influenced by several factors. Hall *et al.* (1944), Lawrie (1958) and Hedrick *et al.* (1959) reported that color intensity of beef muscle was related to high pH. Briskey *et al.* (1958, 1960) reported that an increase in color intensity of pork muscles was also related to high pH.

It was suggested by Lawrie (1950), Millikan (1939) and Shenk *et al.* (1934) that activity during growth influences the amount of pigment in any muscle; however short-term pre-slaughter exercise produced no significant increase in pigment concentration (Briskey *et al.* 1959). Age of animal has been reported by Whipple (1926) and Lawrie (1950) to influence myoglobin concentration. Lawrie (1950), Wilson *et al.* (1959) and Henry and Bratzler (1960) reported that they found no relationship between nutrition and amount of pigment in the muscle. Two-toned color of ham muscle, according to Wilson *et al.* (1959), was influenced my myoglobin concentration.

The purpose of this paper is to present data showing the effects of adrenaline administration on pH, color appearance, and pigment concentration of certain muscles of the lamb carcass.

Experimental

Sixty-four lambs weighing from 85 lb. to 115 lb. live weight were used in this study. The carcasses varied from intermediate maturity to more mature according to U.S.D.A. Grade Standards of 1957. Thirty-two of the lambs were crossbred wethers, 24 of which were given subcutaneous adrenaline injections at 8 and 24 hours pre-slaughter. The dosages given were 2, 3, 4 and 5 mg. of aqueous adrenaline solution per 100 lb. live weight at each of the two pre-slaughter intervals. The remaining 32 lambs were purebred Hampshire, Shropshire and Corriedale wether lambs and were not intentionally stressed. However, the purebred lambs were used for judging and live animal evaluation classes and were shorn one day pre-slaughter during cold weather. The approximate temperature range during this period was 30–50° F.

The lambs were slaughtered and the carcasses chilled for 24 hours at 36–38° F. Flank muscles were subjectively scored for color, using a hedonic scale ranging from 1=very pale pink to 7=dark red. The right *rectus abdominis* muscle was removed for pH and myoglobin determinations. The procedure for myoglobin determination was that of Ginger *et al.* (1954). Carcasses of the crossbreds and nine of the purebreds were ribbed posterior to the last rib for pH determinations of the *longissimus dorsi* muscle. The carcass grades for the crossbreds were High Utility=1, Low Good=11 and Average Good=20. Carcasses of the purebreds ranged in grade from High Good to Low Prime. U.S.D.A. grade standards issued in 1957 were applied. The data were treated by analysis of variance and by use of correlation coefficients.

Results and Discussion

Data on the effects of pre-slaughter adrenaline injections upon the color of flank muscles and pH of the *rectus abdominis* and *longissimus dorsi* muscles are presented in figures 1, 2 and 3. Flank muscles of the carcasses from treated lambs were darker in color than the controls. As the dosage of adrenaline was increased the pH of the *rectus abdominis* and *longissimus dorsi* muscles increased.

Correlation coefficients were calculated for the various objective and subjective measures studied and are presented in table 1. Data in figure 1 and table 1 suggest that color of an individual muscle in lamb carcasses is influenced more by pH than by myoglobin content. The color of flank muscles became

[1] Contribution from Missouri Agricultural Experiment Station, Journal Series No. 2254 approved by the Director.

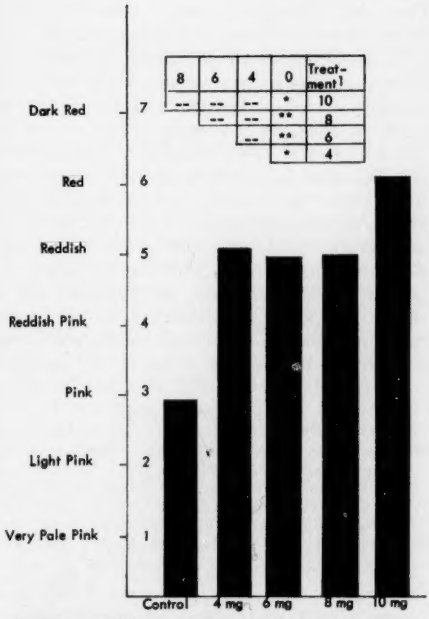


Figure 1. Effect of subcutaneous injections of Adrenaline on the subsequent color of the flank muscles of lamb carcasses. * P<.05, ** P<.01, [1] Mg. adrenaline/100 lb. live weight.

progressively darker at higher pH levels. The pH of the muscle was progressively higher as the dosage of adrenaline injected pre-slaughter was increased (figures 2 and 3).

The pH values of the *rectus abdominis* muscle of the purebred lambs varied from 5.75 to 6.85. Color of the flank muscles was also progressively darker as pH increased. This variation in pH value may be attributed to variation in pre-slaughter stress caused by handling the animals.

The above results support the findings of Hall *et al.* (1944), Lawrie (1958), Briskey *et al.* (1959) Hedrick *et al.* (1959), and Radouco-Thomas *et al.* (1959), who reported that color intensity of muscle was related to high pH. When lambs were subjected to physiological stress for several hours pre-slaughter muscle glycogen apparently was reduced, resulting in high ultimate (24-hour) pH and dark color muscle. Similar studies were reported by Radouco-Thomas *et al.* (1959) who found that increased dosage of adrenaline pre-slaughter to rabbits resulted in increased pH of the *longissimus dorsi* muscle. Hedrick *et al.* (1959) reported similar findings in beef cattle. Pre-slaughter adrenaline injections resulted in an increase in blood sugar level and a reduction in muscle glycogen.

The average myoglobin concentrations of the *rectus abdominis* muscle was 2.00 ± 0.53 mg./gm. of fresh tissue. The range in carcass grade was High Utility to Low Prime. Lower grade carcasses contained significantly ($P < 0.01$) more myoglobin than higher grade carcasses. As pH of muscle increased the amount of myoglobin extracted decreased significantly ($P < 0.01$). There was no significant relationship between color score of the flank muscles and myoglobin content.

Summary

Sixty-four lambs were used to determine the effect of pre-slaughter adrenaline injec-

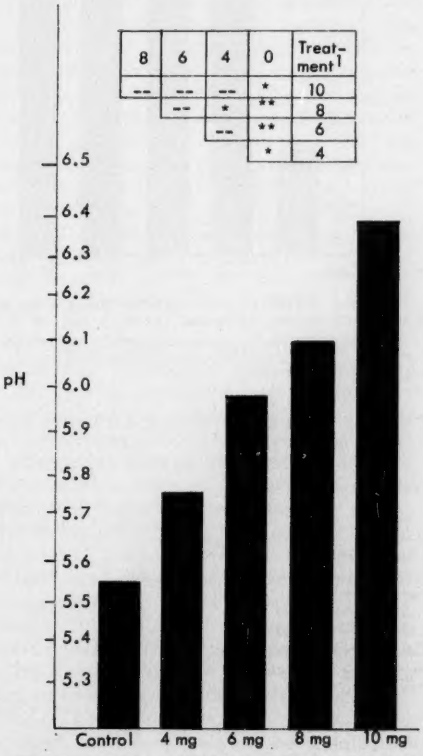


Figure 2. Effect of subcutaneous injections of Adrenaline on the ultimate (24 hr.) pH of the longissimus dorsi muscle of lamb carcasses. * P<.05, ** P<.01, [1] Mg. adrenaline/100 lb. live weight.

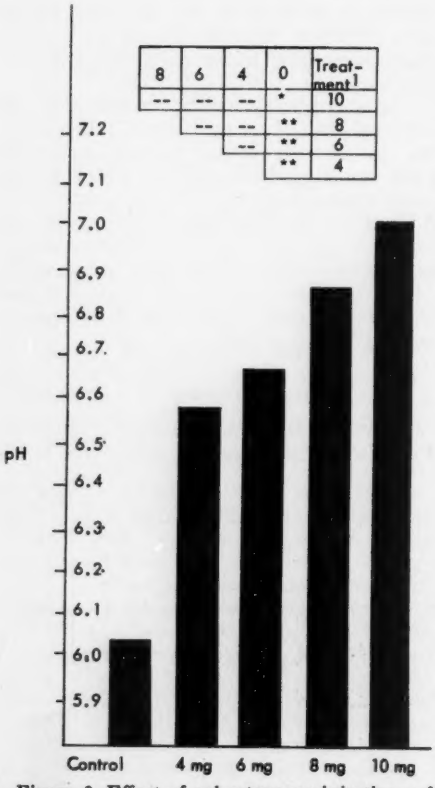


Figure 3. Effect of subcutaneous injections of Adrenaline on the ultimate (24 hr.) pH of the rectus abdominis muscle of lamb carcasses. * P<.05, ** P<.01, [1] Mg. adrenaline/100 lb. live weight.

TABLE 1. CORRELATION COEFFICIENTS FOR CERTAIN OBJECTIVE AND SUBJECTIVE MEASUREMENTS OF LAMB CARCASSES

Item	Number of carcasses	Correlation coefficient
Color score vs. pH *rectus abdominis*	64	0.51**
Color score vs. pH *longissimus dorsi*	41	0.52**
Color score vs. Grade [1]	32	0.22
Color score vs. Myoglobin	64	0.22
Myoglobin vs. Grade	64	0.50**
Myoglobin vs. pH *rectus abdominis*	64	−0.36**
Grade vs. pH *rectus abdominis* [1]	32	0.09
Grade vs. pH *longissimus dorsi*	41	0.13
pH *rectus abdominis* vs. pH *longissimus dorsi*	41	0.64**

[1] Untreated.
** P<.01.

tions on subsequent carcass characteristics. Flank muscles from adrenaline-treated animals were significantly darker in color and presented higher pH values than untreated animals. Color scores and pH values of the flank muscles were related to pH values of the *longissimus dorsi* muscle. Color of flank muscles was not related to myoglobin content. There was a significant inverse relationship between myoglobin content of the *rectus abdominis* muscle and pH of the *rectus abdominis* muscle. The increase in color intensity of lamb muscle, as measured by a subjective panel, apparently was influenced more by changes in muscle consistency due to higher pH than by quantity of pigment.

Literature Cited

Briskey, E. J., R. W. Bray, W. G. Hoekstra, R. H. Grummer and P. H. Phillips. 1959. The effect of various levels of exercise in altering the chemical and physical characteristics of certain pork ham muscles. J. Animal Sci. 18:153.

Briskey, E. J., W. G. Hoekstra, R. W. Bray and R. H. Grummer. 1960. A comparison of certain physical and chemical characteristics of eight pork muscles. J. Animal Sci. 19:214.

Ginger, Irene D., G. D. Wilson and B. S. Schweigert. 1954. Biochemistry of myoglobin. I. Quantitative determination on beef and pork muscle. J. Agr. Food Chem. 2:1037.

Hall, J. L., C. E. Latschar and D. L. Mackintosh. 1944. Part IV. Characteristics of dark-cutting beef survey and preliminary investigation. Kan. Agr. Exp. Sta. Tech. Bul. 58.

Hedrick, H. B., J. B. Boillot, D. E. Brady and H. D. Naumann. 1959. Etiology of dark-cutting beef. Mo. Agr. Exp. Sta. Res. Bul. 717.

Henry, W. E. and L. J. Bratzler. 1960. Effect of mineral supplementation on pork muscle color as measured by spectrophotometry and disk colorimetry. J. Animal Sci. 19:1195.

Lawrie, R. A. 1950. Some observations on factors affecting myoglobin concentrations in muscle. J. Agr. Sci. 40:356.

Lawrie, R. A. 1958. Physiological stress in relation to dark-cutting beef. J. Sci. Food Agr. 11:721.

Millikan, G. A. 1939. Muscle hemoglobin. Physiol. Rev. 19:503.

Radouco-Thomas, C., C. Lataste-Dorolle, R. Zender, R. Busset, H. M. Meyer, and R. F. Mouton. 1959. The anti-autolytic effect of epinephrine in skeletal muscle: non-additive process for preservation of meat. Food Res. 24:453.

Shenk, John H., J. Lowe Hall and H. H. King. 1934. Spectrophotometric characteristics of hemoglobins. I. Beef blood and muscle hemoglobins. J. Biol. Chem. 105–741.

Whipple, G. H. 1926. The hemoglobin of striated muscle. I. Variations due to age and exercise. Am. J. Physiol. 76:693.

Wilson, George D., Irene D. Ginger and B. S. Schweigert. 1959. A study of the variations of myoglobin concentration in "two-toned" hams. J. Animal Sci. 18:1080.

INVESTIGATIONS ON THE FEEDING OF ALL-CONCENTRATE RATIONS TO BEEF CATTLE [1]

MILTON B. WISE, T. N. BLUMER, G. MATRONE AND E. R. BARRICK

North Carolina Agricultural Experiment Station, Raleigh [2]

CONSIDERABLE interest has developed recently in the feeding of all-concentrate rations to ruminants; however, this is not a new concept. Davenport (1897) and McCandlish (1923) were unsuccessful in attempts to rear calves on rations devoid of roughage and concluded that fibrous materials are necessary in the diet of ruminants. Huffman (1928) agreed with earlier reports and postulated an unknown factor in hay necessary to maintain health of cattle. By additions of cod liver oil and alfalfa ash, Mead and Regan (1931) were able to secure satisfactory growth of calves to 19 months of age on a mixture of barley, oats, wheat bran and linseed meal. The authors stated that the failure to secure continued normal growth of calves in earlier work resulted from a deficiency of Vitamin A alone or in conjunction with an inadequate supply of certain minerals and not from lack of roughage or bulk *per se*.

More recently Matrone *et al.* (1957, 1959a, 1959b) reported results of studies with purified diets for lambs. When sodium and potassium salts of the volatile fatty acids, acetic, propionic and butyric were substituted for starch and a portion of the glucose, growth response was markedly improved. Subsequent studies showed that similar favorable responses could be obtained by adding the sodium and potassium as bicarbonates and deleting the fatty acids, indicating that the role of the cations was most probably associated with the buffering capacity of the rumen. A report by Geurin *et al.* (1959) indicated that adequately supplemented barley promoted rapid gains in fattening cattle whenever the barley was rolled to preserve the roughage characteristic of the hulls.

The research presented herein was designed to determine the effect of a low-fiber, all concentrate basal ration on performance and carcass characteristics of growing-finishing beef calves and to ascertain the influence of sodium and potassium salts and hay in ground or long form on the growth promoting properties of the all-concentrate ration.

Experimental

Two experiments were conducted with calves. Experiment I was a growth-performance study designed to determine the effect on performance of addition of sodium and potassium bicarbonate to an all-concentrate diet, based on ground shelled corn and urea. Experiment II included measurements on carcass characteristics as well as performance data when a similar basal diet was supplemented with either sodium and potassium acetate, ground hay or long hay. In both experiments the animals were kept in concrete-floor tie-stalls with no bedding. Water was available at all times in automatic waterers. Observations were made several times daily for bloat and diarrhea.

Experiment I

Procedures. Ten Hereford steer calves averaging 530 lb. initially were selected from a total of 20 steers on the basis of similiarity in age and weight and randomly assigned to individual pens. The animals were fed a pre-experimental ration based on ground ear corn over a 10-day transition period designed to change the calves gradually to their respective experimental diets. During this transition period, each animal received 10 lb. of feed per head daily; and on each consecutive day an additional pound of the experimental diet was substituted for a pound of the pre-experimental ration. Hence, upon completion of this 10-day transition period, five animals were receiving each of the diets presented in table 1. The amount offered was gradually increased until each animal had reached its maximum intake level. *Ad libitum* feeding was continued throughout the 91-day experimental period.

Feed was weighed and added to the con-

[1] Published with the approval of the director of the North Carolina Agricultural Experiment Station as Paper No. 1284 of the journal series.

[2] Animal Industry Department.

TABLE 1. COMPOSITION OF DIETS—Experiment I

Ingredients	Basal	Basal + Na & K
	%	%
Ground shelled corn	95.1	84.6
Urea	1.0	1.0
Cottonseed oil	2.0	2.0
Na Cl	0.5	...
Ca CO_3	0.7	0.7
Defluorinated phosphate	0.2	0.2
Trace minerals [a]	0.4	0.4
Vitamin A & D concentrate [b]	0.1	0.1
Na H CO_3	...	4.0
K H CO_3	...	7.0

[a] Per 100 lb. of diet was added 0.893 gm. $CuSO_4 \cdot 5H_2O$, 7.648 gm. $FeSO_4 \cdot 2H_2O$, 1.399 gm. $MnSO_4 \cdot H_2O$, 2.263 gm. ZnO, 0.009 gm. $CaCO_3$, 138.000 gm. NH_4Cl and 150.212 gm. Glucose.
[b] 600 gm. of Vitamin A concentrate containing 5000 I.U. of Vitamin A activity per gram and 3 gm. of Vitamin D concentrate containing 165,300 I.U. of Vitamin D per gram in each ton of diet.

tainers daily to assure a fresh supply. Body weights were taken initially and at biweekly intervals thereafter. Near the end of the experiment samples of rumen contents were taken by stomach tube from two randomly chosen calves on each diet and filtered through 3 layers of cheese cloth. The filtrate was preserved with mercuric chloride (1:1000 in preserved sample) and then frozen. Volatile fatty acid analyses were subsequently determined by the method of Keeney (1955).

Results. Feed intake of calves fed the diet containing 11% of sodium and potassium bicarbonate was depressed (table 2). Available energy was further decreased by the presence of the salts. Both these factors are reflected in the daily gains of calves on the diet containing the sodium and potassium salts. Feed intake and body weight gains on the basal diet (11.03 lb. and 1.89 lb., respectively) were quite satisfactory and exceeded expectations. The feed conversion values on the basal diet, averaging 5.83 lb. of feed per pound of body weight increase, were indeed favorable compared to ratios of 8 or 9 to 1 normally obtained on ruminant rations.

Although there appeared to be differences in rumen volatile fatty acid production on the two diets (table 2), the number of observations per mean were limited; therefore, no definite conclusions were drawn. Comparison of these values with literature values from animals on "normal" hay-grain rations revealed that acetate and butyrate were decreased and propionate and valerate plus higher fatty acids were increased. Volatile fatty acid fractions agreed with those found by Matrone *et al.* (1959a) when lambs were fed purified diets.

TABLE 2. PERFORMANCE AND RUMEN VOLATILE FATTY ACIDS OF CALVES FED AN ALL-CONCENTRATE DIET WITH AND WITHOUT SODIUM—AND POTASSIUM BICARBONATES—Experiment I

	Basal	Basal + Na & K
No. animals	5	5
Days on experiment	91	91
Av. initial wt., lb.	528	531
Av. final wt., lb.	700	597
Av. daily gain, lb.	1.9	0.7
Av. daily feed intake, lb.	11.0	9.2
Feed/lb. gain, lb.	5.8	12.7
Volatile fatty acids in rumen contents: [a]		
Acetic, molar %	49.1	56.4
Propionic, molar %	29.3	25.4
Butyric, molar %	5.3	7.5
Valeric & higher, molar %	16.4	10.7

[a] Near end of experiment. Average of 2 calves on each treatment.

The success attained with the basal diet in Experiment I stimulated further research to determine whether or not the addition of hay or its proposed rumen fermentation end product, acetate, would stimulate performance of calves fed the basal diet.

Experiment II

Procedures. Twenty-four Hereford calves (16 steers and 8 heifers), averaging 423 lb. initially, were randomly assigned on the basis of body weight within sexes to four treatments. One treatment consisted of the basal diet (table 3) fed *ad libitum*. In a second treatment, 5% of the ground shelled corn

TABLE 3. COMPOSITION OF BASAL DIET [a]—Experiment II

Ingredient	Percent
Ground shelled corn	95.1
Urea	1.0
Cottonseed oil	2.0
Ca CO_3	0.7
Defluorinated phosphate	0.2
Vitamin A & D concentrate [b]	0.1
Trace mineralized salt	0.9

[a] Analyzed 11.5% total protein and 1.5% crude fiber.
[b] 600 gm. of Vitamin A concentrate containing 5000 I.U. of Vitamin A activity per gram and 3 gm. of Vitamin D concentrate containing 165,300 I.U. of Vitamin D per gram in each ton of basal diet.

in the basal diet was replaced with the same amount of a mixture of two parts sodium acetate and three parts potassium acetate. In a third treatment, 2.5 lb. of ground Coastal Bermuda-grass hay was mixed with the *ad libitum* fed basal diet at time of feeding. The fourth treatment consisted of the basal diet *ad libitum* with 2.5 lb. of long Coastal Bermuda-grass hay fed separately.

Housing and handling procedures as well as the method of starting the calves on their experimental diets were similar to those presented for Experiment I. At the end of the 119-day feeding period, the animals were transported 80 miles to a slaughter plant where shrunk weights, carcass grades and carcass weights were determined. A rib section including the 9th, 10th, 11th and 12th ribs was removed and returned to the laboratory for further study.

Ether extract was determined on moisture free samples of the *Longissimus dorsi* muscle (12th rib area) by the method described in A.O.A.C. (1950). Physical separation of the 9–10–11 rib cut into fat, lean and bone was accomplished according to the procedure outlined by Hankins and Howe (1946). Rind thickness and area of ribeye were measured as proposed by Naumann (1951). The method used for measuring intramuscular fat deposits was described by Blumer and Fleming (1959).

Results. Performance data from Experiment II are presented in table 4.

Intake of the basal diet was remarkably similar on all treatments ranging from 12.5 to 13.1 lb. per head daily. The presence of 5% sodium and potassium acetate did not appear to limit intake, nor did the presence of hay in the ration seem to cause any significant increase in consumption of the basal diet. Weight gains were similar on the basal and the basal plus hay in either ground or long form. Daily gains on the diet containing acetate were 2.24 lb. compared to 2.50 lb. on the basal alone; however, this difference was not statistically significant ($P>0.05$). Conversion of nutrients was most efficient on the basal diet. Slightly more feed (0.57 lb.) was necessary per pound of gain on the ration with acetate added. On the treatments with added hay, approximately the same amount of basal diet (5 lb.) was needed per pound gain as for the basal; however, 1 lb. of hay was also used per pound of weight gain.

Results of the carcass study are shown in table 5. Differences in overnight shrink and dressing percentage were small and no trends were apparent. Slaughter and carcass grades were similar, but a slight tendency toward higher grades on the basal diet and decreased grades on the diet containing acetate was in evidence. These trends were accentuated in the objective measures of degree of finish. Rind fat covering was significantly thinner, and percentage moisture was significantly greater ($P<0.05$) among calves fed the diet containing the acetate salts compared to calves fed the other three diets. Measurements of marbling indicated a slightly higher degree of fat interspersion in muscular tissue among calves fed the basal alone compared to calves fed hay, and calves receiving acetate salts had less interspersed fat in a similar comparison. Ether extract in the *Longissimus dorsi* was similar for calves on all diets except the one containing acetate. Extractable intra-muscular fat was lowest among calves on the acetate containing diet.

TABLE 4. PERFORMANCE OF CALVES FED AN ALL-CONCENTRATE BASAL DIET ALONE OR SUPPLEMENTED WITH Na & K ACETATE, GROUND HAY OR LONG HAY—Experiment II

Criterion	Basal	Basal + Na & K acetate	Basal + Ground hay	Basal + Long hay
No. animals	6	6	6	6
Days on experiment	119	119	119	119
Av. initial wt., lb.	428	410	434	420
Av. final wt., lb.	726	676	741	716
Av. daily gain, lb.	2.5	2.2	2.6	2.5
Av. daily feed intake, lb.:				
Basal	12.5	12.5	12.8	13.1
Hay	...	...	2.5	2.5
Feed/lb. gain, lb.:				
Basal	5.0	5.6	5.0	5.2
Hay	...	...	1.0	1.0

TABLE 5. CARCASS CHARACTERISTICS OF CALVES FED AN ALL-CONCENTRATE BASAL DIET ALONE OR SUPPLEMENTED WITH Na & K ACETATE, GROUND HAY OR LONG HAY—Experiment II

Criterion	Basal	Basal + Na & K acetate	Basal + Ground hay	Basal + Long hay
Av. shrunk live wt., lb.	700	656	724	698
% Shrink (overnight)	3.7	3.1	2.3	2.6
Av. carcass wt., lb.	407	382	406	401
Dressing percent	58.2	58.2	56.1	57.4
Av. grade: [a]				
Final live, slaughter	10.7	9.0	10.7	10.7
Carcass	11.3	9.7	10.3	10.8
9–10–11 Rib cut separation:				
% Fat	37.9	28.4	35.5	34.6
% Lean	47.6	54.6	49.1	50.8
% Bone	14.5	17.0	15.3	14.6
Rind thickness, mm.	21.0	10.6	16.6	21.5
Measurements on cross-section of *Longissimus dorsi* muscle at 12th rib:				
Moisture, %	70.5	72.9	70.4	70.4
Ether extract, %	5.5	4.4	5.6	5.5
Total no. fat deposits per sq. in.	6.2	4.4	5.8	4.9
Area of fat deposits >2 sq. mm. per sq. in., sq. mm.	49.6	35.0	45.1	42.8
Area, sq. in.	8.3	8.1	8.1	8.8

[a] Based on high good as 11, middle good as 10, low good as 9, etc.

Discussion

The data presented, herein, indicate that the ruminant can perform "normally" for extended periods on rations devoid of roughage but otherwise balanced nutritionally. It would be difficult indeed to construct a ration from natural feedstuffs with a lower fiber content (1.5%) than the basal diet used in these studies.

Although Matrone *et al.* (1957, 1959a) reported satisfactory gains of lambs on purified diets containing 11% of sodium and potassium bicarbonate, it is apparent from the results in Experiment I that this level of cation supplementation was too high for calves fed an all-concentrate diet constructed from natural feedstuffs. This does not negate the concept that monovalent cations may be of extreme importance in the enhancement of rumen buffering capacity when highly fermentable substrates are offered to the ruminant but would suggest that a lower level than that used in this experiment may be sufficient. Since the basal ration used in both experiments contained 1% urea, it is possible that the ammonia released from this product and converted to the cationic form (NH_4^+) may have been present in sufficient quantities to increase buffering capacity of the rumen and to aid in neutralization of the rapidly formed volatile fatty acids. Further work is in progress to define the types and levels of buffering agents which will allow maximum response of ruminants to all-concentrate diets.

One observation, not apparent in the data as presented, was performance of the calves during the period of transition from a ration containing roughage to the all-concentrate diets in Experiment II. It should be noted that body weight gains during this period were somewhat higher for calves receiving hay in their diet; however, this initial advantage of calves on the rations containing hay was overcome by slightly more rapid gains of calves on the basal diet during the subsequent portion of the experiment. Desirability of gradual removal of the roughage portion of the diet to allow adaptation of the microbial population of the rumen may be indicated in this observation.

Diarrhea was a problem only among calves fed the high levels of sodium and potassium bicarbonate during Experiment I. This was perhaps due to the influence of the high concentrations of salts in the gastro-intestinal tract on osmotic relationships. Bloat was not encountered in either experiment. The presence of 2% cottonseed oil in all diets may have had a beneficial influence with respect

to bloat prevention (Brown *et al.*, 1958). The fact that feed was available continuously to the animals may have caused a more uniform intake with respect to time, thus preventing "overloading" of the rumen, hence reducing the likelihood of the occurrence of bloat.

Summary

Thirty-four Hereford calves were used in two experiments to determine the feasibility of feeding all-concentrate rations to beef cattle. In the first experiment which was a growth-performance study, a basal diet containing 1.5% fiber and composed of ground shelled corn, urea, cottonseed oil, minerals and vitamins was compared to a similar diet with sodium and potassium bicarbonate added at a level of 11% of the total ration. This level of cation supplementation proved to be excessive; however, performance on the basal diet (1.89 lb. daily) stimulated a second experiment. In this study which included carcass evaluation as well as growth-performance, the basal diet was supplemented with either 5% sodium and potassium acetate or 2.5 lb. per day of ground or long hay. Performance of calves on the unsupplemented basal ration equaled that of calves fed any of the other three diets. Feed conversion on the basal ration alone was slightly superior to conversion on diets containing acetate salts or hay in either form. The presence of acetate salts in the diet adversely affected growth-performance and produced carcasses with less finish than the other three diets. On the basis of these data, it was concluded that calves are able to perform satisfactorily on all-concentrate rations for extended periods of time if the ration provides essential nutrients in adequate amounts and the buffering capacity of the rumen is adequate. The possible rumen buffering capacity of ammonium ions from urea is discussed. Types and levels of buffering agents in all-concentrate rations for ruminants merit further study.

Literature Cited

A.O.A.C. 1950. Official methods of analysis (7th ed.) Association of Official Agricultural Chemists. Washington, D. C.

Blumer, T. N. and H. P. Fleming. 1959. A method for the qualitative estimation of marbling in the beef ribeye muscle. J. Animal Sci. 18:959.

Brown, L. R., R. H. Johnson, N. L. Jacobson and P. G. Homeyer. 1958. Effects of administration of oils and of penicillin on incidence and severity of bloat and certain other responses of cattle. J. Animal Sci. 17:374.

Davenport, E. 1897. On the importance of the physiological requirements of the animal body; Results of an attempt to grow cattle without coarse feed. Ill. Agr. Exp. Sta. Bul. 46:362.

Geurin, H. B., J. L. Williamson, J. C. Thompson, H. L. Wilcke and R. M. Bethke. 1959. Rolled common barley serves as both grain and roughage for fattening steers. J. Animal Sci. 18:1489.

Hankins, O. G. and P. E. Howe. 1946. Estimation of the composition of beef carcasses and cuts. U.S.D.A. Tech. Bul. 946.

Huffman, C. F. 1928. Hay is necessary in ration of dairy cattle; unknown factor present in hay needed to maintain health of dairy cattle. Mich. Exp. Sta. Quarterly Bul. XI, (1):3.

Keeney, M. 1955. Direct chromatographic determination of C_1 to C_6 fatty acids in rumen fluid. U. Md. Misc. Pub. 238:23.

Matrone, G., H. A. Ramsey and G. H. Wise. 1957. Purified diets for ruminants. Proc. Soc. Exp. Biol. and Med. 95:731.

Matrone, G., H. A. Ramsey and G. H. Wise. 1959a. Effect of volatile fatty acids, sodium and potassium bicarbonate in purified diets for ruminants. Proc. Soc. Exp. Biol. and Med. 100:8.

Matrone, G., H. A. Ramsey and G. H. Wise. 1959b. Role of sodium and potassium cations in volatile fatty acid metabolism of ruminants. Proc. 1959 Cornell Nutr. Conf. for Feed Manuf. p. 36.

McCandlish, A. C. 1923. Studies in the growth and nutrition of dairy calves. V. Milk as the sole ration for calves. J. Dairy Sci. 6:54.

Mead, S. W. and W. M. Regan. 1931. Deficiencies in rations devoid of roughage for calves. I. The effect of the addition of cod liver oil and alfalfa ash. J. Dairy Sci. 14:283.

Naumann, H. D. 1951. A recommended procedure for measuring and grading beef for carcass evaluation. Proc. 4th Ann. Reciprocal Meat Conf. p. 89.

HERITABILITY OF LITTER SIZE IN SWINE[1]

W. J. Boylan, W. E. Rempel and R. E. Comstock

University of Minnesota, St. Paul

ESTIMATES of heritability of litter size in swine accompanied by low standard errors are difficult to obtain. Consequently, it is not surprising that a wide range of estimates have been reported. In an earlier review Lush and Molln (1942) found estimates for heritability of litter size ranging from 0.10 to 0.44 and reported their own estimate of 0.17. Subsequently estimates have been reported ranging from —.11 (Cockerham, 1952) to 0.54 (Shelby, 1952). Considerable data have accumulated at the University of Minnesota since estimates were made and reported by Stewart (1945b) and Cummings *et al.* (1947). The purpose of this study was to obtain further information on heritability of litter size in swine from these data.

Source of Data

The data used were collected in the Minnesota swine breeding project of the Regional Swine Breeding Laboratory of the U.S. Department of Agriculture. They pertain to animals in three inbred lines of swine developed at the Minnesota station. These lines were the Minnesota No. 1 (Winters *et al.*, 1943), the Minnesota No. 2 (Roubicek *et al.*, 1951) and the Minnesota No. 3 (Sumption, 1957). The data were obtained at the following four stations in Minnesota: the North Central at Grand Rapids (NC), the Central at Rosemount (R), the Northwest at Crookston (NW) and the West Central at Morris (WC).

The animals from which the data were obtained included litters farrowed during the years from 1943 for the Minnesota No. 1, from 1942 for the Minnesota No. 2 and from 1953 for the Minnesota No. 3. For all lines the final data used were on 1959 spring-farrowed litters.

Methods and Analyses

The measure of litter size employed was number of pigs born alive in the first litter farrowed by the various females.

An estimate of heritability in the narrow sense was obtained by intra-group regression of the record of the performance of a daughter on the record of performance of her dam. The litter size record of each dam was paired with that of each of her daughters that had farrowed, i.e., the information from a dam and her daughters was weighted in proportion to the number of daughters.

Estimates of daughter-dam regression were computed on an intra-season, line and station basis. This was accomplished through a between and within group analysis of variance and covariance, each "group" of data being comprised of records on dams of a single line that had farrowed their first litters in the same year, season and location and daughters that had farrowed their first litters in the same year, season and location. The data were analyzed on an intra-group basis rather than on an intra-sire basis because this method meant substantially more degrees of freedom and smaller standard errors for the estimates. It should be pointed out that, assuming random mating, the expectation of the daughter-dam regression is one-half of heritability whether computed on the intra-sire or intra-group basis. Random mating of selected males and females has been the consistent practice except that brother-sister matings have been avoided.

A regression coefficient for each of the three lines was computed by pooling the data from each station where that line was maintained. Similarly, an overall regression coefficient was computed by pooling the information from all of the lines.

While it is recognized that the age of a gilt at the time of her first litter influences the size of the litter, Stewart (1945a) found that when a correction was made for age (adjusting the litter size to that expected at 12 months) it accounted for only 3% of the total variance in litter size. For this reason no correction was made for age of the females at the time of farrow in this analysis. In general, however, the gilts were bred to farrow their first litters at 12 months of age. The size

[1] Paper No. 4572, Scientific Journal Series of the Minnesota Agricultural Experiment Station, St. Paul, with cooperation of AHRD, ARS, The Regional Swine Breeding Laboratory, U. S. Department of Agriculture.

TABLE 1. SIZE OF FIRST LITTER OF DAUGHTERS AND AGE AT THE TIME OF FIRST LITTER

Line	Years of record	No. of litters	Mean litter size farrowed alive	Age, months
Minn. No. 1	1944–1959	548	9.06	11.95
Minn. No. 2	1942–1959	861	7.85	12.35
Minn. No. 3	1953–1959	561	8.99	11.81
Total		1970	8.51	12.09

of first litter of daughters and age at the time of first litter are shown in table 1.

Results and Discussion

The results of the regression analyses for each of the respective lines at the various stations, as well as pooled values, are given in table 2. The corresponding heritability estimates by lines were as follows: Minnesota No. 1, 0.05 ± 0.13 (548 daughter-dam comparisons); Minnesota No. 2, -0.04 ± 0.10 (861 daughter-dam comparisons); Minnesota No. 3, 0.17 ± 0.14 (561 daughter-dam comparisons). The pooled estimate from all 1970 daughter-dam comparisons was 0.03 ± 0.07.

None of the regression coefficients obtained in the analyses were found to be significantly different from zero or significantly different from each other ($P>.05$).

Stewart (1945b) and Cummings *et al.* (1947) estimated heritability of litter size in some of the same lines of breeding used in this study, but from data collected earlier in the development of the lines. Stewart (1945b) obtained an estimate of 0.16 ± 0.23 based on an intra-sire regression and the records of 475 daughter-dam pairs. Cummings *et al.* (1947) obtained a larger value 0.19 ± 0.14 than Stewart using 532 daughter-dam comparisons. The estimate of heritability of 0.03 ± 0.07 in this study was based on a larger sample than either of the above studies and was subject to a smaller standard error.

Differences in the results found in this study compared to those reported by Stewart (1945b) and Cummings *et al.* (1947) may be largely due to sampling error. However, an increase in homozygosity of the lines should tend to reduce the estimate. This statement is supported by the fact that the calculated mean coefficient of inbreeding has increased and the heritability estimate has decreased.

In comparing estimates between the Minnesota No. 1 and the Minnesota No. 3 the relative magnitude of the values obtained seems plausible. The Minnesota No. 1 has been more closely inbred. The calculated average coefficient of inbreeding for the Minnesota No. 1 was about three times that for the Minnesota No. 3. Furthermore the foundation material from which the Minnesota No. 3 was established was derived from more sources than in the case of the Minnesota No. 1. The Minnesota No. 3 may for that reason possess more genetic variation than the Minnesota No. 1. It should be noted that El-Issawi and Rempel (in press) found little difference

TABLE 2. REGRESSION ANALYSES OF LITTER SIZE DATA

Station	Line	Number of daughter-dam pairs	Degrees of freedom	Regression coefficient[a]	S.E.	Estimate of heritability	S.E.
NC	Minn. No. 1	415	370	0.077	0.083	0.15	0.17
R	Minn. No. 1	133	111	−0.076	0.113	−0.15	0.23
Sub total:	Minn. No. 1	548	481	0.026	0.067	0.05	0.13
NW	Minn. No. 2	387	354	−0.003	0.069	−0.01	0.14
WC	Minn. No. 2	100	96	−0.106	0.154	−0.21	0.31
R	Minn. No. 2	374	343	−0.021	0.073	−0.04	0.15
Sub total:	Minn. No. 2	861	793	−0.020	0.048	−0.04	0.10
WC	Minn. No. 3	117	113	0.300	0.153	0.60	0.31
R	Minn. No. 3	444	433	0.033	0.082	0.07	0.16
Sub total:	Minn. No. 3	561	546	0.083	0.072	0.17	0.14
Grand total:		1970	1820	0.017	0.034	0.03	0.07

[a] Size of daughter's first litter on size of dam's first litter.

between the two lines in estimates of heritability of growth rate though there, as here, the larger figure was obtained for the Minnesota No. 3.

The simplest and most likely explanation for the negative estimate of heritability in the Minnesota No. 2 is that it arose by sampling error. The estimate has a confidence range that extends well above zero.

The values found in this study fall within the range of those reported in the literature. However, except for the Minnesota No. 3 estimate, they fall considerably below the majority previously reported. Estimates reported in the literature indicate that heritability of litter size is usually below 0.18 and that the best estimate of average heritability of the trait is probably less than 0.10.

In view of the low values found in this study and reported in the literature it seems that only a limited amount of mass selection for litter size in swine can be justified. This would permit breeders to place more emphasis on selection for other traits. It should be pointed out however that limited selection pressure may be necessary to maintain established levels of performance even though intense selection is likely to do little in the way of increasing average litter size. Whether selection required to maintain litter size is more than will occur naturally, because larger litters will on the average leave more members in the breeding herd, can hardly be inferred from present evidence.

Summary

Heritability of litter size was studied in three inbred lines of swine. An intra-group regression of the record of the daughter on the record of her dam was made to estimate heritability. A total of 1970 daughter-dam comparisons were made. Only data of the number born alive in the first litter were used.

A heritability estimate for litter size for the Minnesota No. 1 was 0.05 ± 0.13, for the Minnesota No. 2 it was $-.04 \pm 0.10$ and for the Minnesota No. 3 it was 0.17 ± 0.14. An overall heritability estimate for all animals studied was found to be 0.03 ± 0.07. None of the heritability estimates obtained were found to be significantly different from zero or significantly different from each other ($P > .05$).

The values found in this study fall within the range of those reported elsewhere, but are considerably less than a major portion of those reported.

From this study it was concluded that heritability for litter size is low and the response to mass selection for increased performance within a line or breed will be negligible.

Literature Cited

Cockerham, C. C. 1952. Genetic covariation among characteristics of swine. Ph.D. thesis. Iowa State University, Ames, Iowa.

Cummings, J. N., L. M. Winters and H. A. Stewart. 1947. The heritability of some factors affecting productivity of brood sows. J. Animal Sci. 6:297.

El-Issawi, H. F. and W. E. Rempel. Heritability of growth rate in swine. (In press).

Lush, J. L. and A. E. Molln. 1942. Litter size and weight as permanent characteristics of sows. U. S. Dept. of Agr. Tech. Bul. 836.

Roubicek, C. B., L. M. Winters and O. M. Kiser. 1951. A genealogical study of the Minnesota No. 2 hog. Minn. Agr. Exp. Sta. Tech. Bul. 193.

Shelby, C. E. 1952. Genetic aspects of the production registry program of the United Duroc Record Association. Ph.D. thesis. Iowa State University, Ames, Iowa.

Stewart, H. A. 1945a. An appraisal of factors affecting prolificacy in swine. J. Animal Sci. 4:250.

Stewart, H. A. 1945b. The inheritance of prolificacy in swine. J. Animal Sci. 4:359.

Sumption, L. J. 1957. An analysis of the early development of the Minnesota No. 3 inbred line of swine. Ph.D. thesis. University of Minnesota, St. Paul, Minnesota.

Winters, L. M., R. E. Comstock and D. L. Dailey. 1943. The development of an inbred line of swine (Minnesota No. 1) from a crossbred foundation. J. Animal Sci. 2:129.

EFFECT OF HEATING STARCH ON ITS DIGESTION BY RUMEN MICROORGANISMS [1]

R. L. Salsbury, J. A. Hoefer and R. W. Luecke

Michigan State University,[2] East Lansing

When rations that are high in concentrates and low in roughage are fed to cattle, the ratio of acetic acid to propionic acid in the rumen has been found to be lower than the ratio obtained when rations containing moderate amounts of concentrates are fed (Balch *et al.*, 1955). This effect of high concentrate rations is enhanced if a cooked concentrate, such as bread, is used (Shaw *et al.*, 1959) or if the concentrate is heat-treated before being fed (Ensor *et al.*, 1959). Eusebio *et al.* (1959) showed that feeding of such rations altered the microbial metabolism of the rumen, probably by bringing about a change in the relative proportions of the microbial species present in the rumen. It is not clear just how this change is brought about by heating the feed.

The working hypothesis used as the basis for the present investigation was that the heating of starch or starchy feeds used in ruminant rations increases the rate of starch dissimilation in the rumen. It was assumed that this increase in rate alters the proportions of volatile fatty acids by favoring the development of certain rumen microorganisms or saturating certain metabolic pathways, or both. The purpose of this report is to describe experiments to determine whether the heating of starch increases the rate of dissimilation and, if so, by what means this is accomplished.

Experimental

The laboratory fermentations were carried out as described by Salsbury *et al.* (1956; 1958). The disappearance of starch was followed by determining that portion of the dry matter that was hydrolyzed by 0.5 M HCl in one hour at 121° C. This was designated as readily hydrolyzable dry matter (RHDM). Allowance was made for the RHDM present in the inoculum when this was significant, so that in the experiments where starch was used as the substrate, RHDM came close to being a true measure of starch. Where corn was used as the substrate, the RHDM determination could be expected to include some dry matter constituents other than starch. However, it would still give a reasonable estimate of starch disappearance because of the high proportion of starch in the corn, usually not less than 70% of the dry matter.

The procedure for determining the RHDM was as follows. The fermentation mixture was diluted to four times its original volume with absolute ethanol, centrifuged, and the solid material dried and weighed. This was then hydrolyzed with 10 ml. of 0.5 M HCl at 121° C. for one hour, centrifuged from 80% ethanol, washed with ethanol, dried and weighed. It was necessary to wash with ethanol several times to remove all the acid which would otherwise cause charring on subsequent drying. The difference between the weight before and after hydrolysis gave the RHDM of the sample. When the above procedure was repeated for negative controls to which no substrate had been added, the RHDM of the rumen fluid inoculum was obtained. Subtracting the RHDM of the inoculum from that of the fermentation mixture gave the RHDM of the added substrate.

Two kinds of inoculum were used in these experiments; the fluid obtained by squeezing the more liquid portion of rumen ingesta through one layer of cheesecloth (strained rumen fluid), and the supernatant fluid obtained by centrifuging strained rumen fluid in an International Size 2 centrifuge at 1500 rpm for 10 minutes to remove most of the plant material and protozoa (centrifuged rumen fluid).

Results and Discussion

The effect of heat treatment on the rate of digestion of starch is shown in table 1. Centrifuged rumen fluid was used as the inoculum in this experiment. Starch which was suspended in water and boiled for 3 minutes before being used as the substrate was

[1] Published with the approval of the Director of the Michigan Agricultural Experiment Station as Journal Article No. 2775.

[2] Departments of Agricultural Chemistry and Animal Husbandry.

TABLE 1. EFFECT OF HEATING ON THE RATE OF DISAPPEARANCE OF RHDM [a] OF CORN STARCH [b, c]

Incubation time	RHDM disappearance of: Untreated corn starch	Boiled corn starch
hr.	%	%
1	2.5±2.7 [d]	6.2±6.6
2	−.4±2.7	19.4±2.1
3	5.0±0.9	31.4±6.6
6	4.5±1.2	60.0±4.7
9	11.4±1.7	59.4±1.6
12	22.9±2.9	63.9±3.3
24	67.3±4.1	71.9±2.3

[a] RHDM=readily hydrolyzable dry matter.
[b] Each value represents the mean of three fermentations.
[c] Inoculum was centrifuged rumen fluid.
[d] Standard error of the mean.

TABLE 2. EFFECT OF AUTOCLAVING ON THE RATE OF DISAPPEARANCE OF RHDM [a] OF A COMMERCIALLY HEATED CORN [b, c]

Incubation time	RHDM disappearance of: Heated corn	Heated corn autoclaved
hr.	%	%
1	−14.7±3.8 [d]	−9.8±1.2
2	8.5±1.4	−2.5±1.3
3	2.4±1.8	4.7±1.4
6	38.6±2.9	24.8±2.1
9	58.8±1.7	44.0±1.4
12	68.2±1.7	56.1±1.2
24	96.1±1.6	83.6±0.8

[a] RHDM=readily hydrolyzable dry matter.
[b] Each value represents the mean of three fermentations
[c] Inoculum was strained rumen fluid.
[d] Standard error of the mean.

attacked much more rapidly than untreated starch. After incubation for 6 hr., 60% of the readily hydrolyzable dry matter (RHDM) of the boiled starch had disappeared compared to 5% for the untreated starch.

The effect of heat treatment on the rate of disappearance of the RHDM of a commercially heated corn is shown in table 2. In this experiment, strained rumen fluid was used for the inoculum because it was expected that corn would be more resistant to attack than pure starch, but later experiments did not confirm this expectation. The heat was applied by autoclaving the heated corn, rather than boiling it with water, in order to avoid dilution of the inoculum. The rate of digestion of the heated corn was a little slower after autoclaving than before. In this connection, the finding of Leatherwood *et al.* (1960) that autoclaving hay lowered the digestibility of the dry matter and crude protein *in vivo* may be significant. Hence, the decrease in the rate of digestion of the heated corn after autoclaving may represent a decrease in the digestibility of the protein.

In order to determine the heating conditions necessary to make starch rapidly digestible, a number of treatments were examined. These included dry heat of approximately 100° C. for 12 hours, autoclaving 10 minutes at 121° C. without the addition of any water, autoclaving a mixture of two parts of starch to one part of water, and autoclaving a mixture of one part of starch to 18 parts of water. The relatively low temperature of 100° C. was used for the dry heat treatment in order to avoid loss of identity of the starch by dextrinization. For a sixth treatment, bread was used because it had been shown to be effective in lowering milk fat when fed to cattle and in lowering the ratio of acetic to propionic acid in the rumen (Shaw *et al.*, 1959). Thus, if the working hypothesis used as the basis for the present investigation was correct, bread should be digested rapidly.

The effects of the various heat treatments on the rate of starch disappearance *in vitro* are given in table 3. Centrifuged rumen fluid was used as the inoculum for these experiments. During the first 3 hours of incubation there

TABLE 3. EFFECT OF VARIOUS HEAT TREATMENTS ON THE RATE OF DISAPPEARANCE OF RHDM [a] OF CORN STARCH AND BREAD [b]

Incubation time	RHDM disappearance of: Untreated	Dry heated	Autoclaved	Autoclaved (0.5 part water)	Autoclaved (18 parts water)	Bread
hr.	%	%	%	%	%	%
3	−2.1±0.4 [c]	0.2±1.7	3.2±1.1	−3.6±25.9	29.6±1.4	36.8±0.7
6	12.2±0.8	13.7±1.5	18.9±0.7	42.6±12.9	67.4±1.2	50.1±1.4
9	26.9±2.4	42.0±1.0	39.2±1.7	60.9±13.7	71.7±4.9	54.1±0.8
12	49.9±6.5	53.9±4.3	54.3±1.4	70.4±13.7	67.4±1.2	55.8±0.7

[a] RHDM=readily hydrolyzable dry matter.
[b] Each value represents the mean of three fermentations.
[c] Standard error of the mean.

was no appreciable digestion of untreated, dry heated, autoclaved starch, or starch autoclaved with one-half part of water. Starch subjected to dry heat showed slightly more rapid digestion than untreated starch, but this increase in rate did not occur until the second half of the 12-hour fermentation period. Autoclaving without water gave essentially the same rate of digestion as dry heat. Autoclaving under these conditions is, in effect, applying a relatively dry heat, particularly if the steam is introduced and released rapidly. When two parts of starch were autoclaved with one part of water, the rate of digestion of the starch was increased considerably. The greater variation in results obtained with this treatment is probably a reflection of the uneven mixing of starch and water which resulted in the formation of aggregates of starch grains. Since inoculation involved the suspension of the starch in rumen fluid and the pipetting of aliquots of the suspension into sacs, this uneven distribution led to considerable variation in the amount of starch transferred.

The most rapid digestion of corn starch was obtained when it was suspended in 18 parts of water before autoclaving. Under these conditions the starch grains had burst and, presumably, maximum hydration had been obtained. Thirty percent of the starch treated in this manner disappeared in the first 3 hours of incubation. This was surpassed only by bread, which showed a disappearance of 37% of the RHDM in 3 hours. The slower subsequent rate of disappearance shown by bread may have been due to the presence of ingredients other than starch or, more probably, to the retrogradation of some of the starch.

Since autoclaving or boiling with an excess of water appeared to be the most effective heat treatment, the commercially heated corn was reexamined. Centrifuged rumen fluid was used as the inoculum. Autoclaving heated corn with 18 parts of water appeared to increase the rate of digestion, since 50% of the RHDM was digested in 6 hours compared to 39% for heated corn that had not been autoclaved (table 4). A comparison was also made of the rates of digestion of the RHDM of ground corn which had not been treated, ground corn after autoclaving without added water, and after boiling with 18 parts of water. In this experiment it was necessary to weigh the untreated ground corn and the autoclaved ground corn directly into the sacs in order to avoid excessive variation in the samples. The ground corn that was boiled with water was inoculated in the usual manner. Both the dry-autoclaved heated corn (table 2) and the dry-autoclaved ground corn (table 4) showed a decreased rate of RHDM digestion. Boiling ground corn with 18 parts of water resulted in an appreciable increase in the rate of RHDM digestion over that shown by untreated ground corn.

TABLE 4. EFFECT OF AUTOCLAVING ON THE DISAPPEARANCE OF RHDM [a] OF A COMMERCIALLY HEATED CORN AND OF GROUND CORN [b]

Incubation time	RHDM disappearance of:				
	Heated corn	Heated corn autoclaved with water [c]	Ground corn	Ground corn autoclaved [d]	Ground corn boiled with water
hr.	%	%	%	%	%
3	22.5±2.7 [e]	21.1±1.2	6.7±0.7	0.9±0.5	11.5±9.3
6	39.3±2.7	50.4±1.1	11.2±0.5	10.4±0.6	32.0±2.2
9	50.1±3.0	53.4±0.8	31.5±3.4	22.2±1.2	47.7±2.5
12	56.4±2.9	57.0±1.0	42.7±1.1	30.9±0.7	63.7±2.5
24	62.3±3.0	62.0±1.6	74.0±0.8	59.3±0.6	80.8±2.6

[a] RHDM = readily hydrolyzable dry matter.
[b] Each value represents the mean of three fermentations.
[c] Eighteen parts of water added before autoclaving.
[d] No water added before autoclaving.
[e] Standard error of the mean.

Summary

Corn starch, ground corn, and a commercially heated corn were exposed to various heat treatments and the effect of the treatments on the digestion of the readily hydrolyzable dry matter (RHDM) of these materials by rumen microorganisms was examined. Results were in keeping with the concept that the application of moist heat to starch or starchy feeds brings about hydration of the starch and that hydrated starch is digested

more rapidly by rumen microorganisms than untreated starch. Autoclaving ground corn or a commercially heated corn without the addition of water resulted in a decrease in the rate of digestion of the RHDM.

Literature Cited

Balch, C. C., D. A. Balch, S. Bartlett, M. P. Bartrum, V. M. Johnson, S. J. Rowland and J. Turner. 1955. Studies of the secretion of milk of low fat content by cows on diets low in hay and high in concentrates. VI. The effect on the physical and biochemical processes of the reticulo rumen. J. Dairy Res. 22:270.

Ensor, W. L., J. C. Shaw and H. F. Tellechea. 1959. Special diets for the production of low fat milk and more efficient gains in body weight. J. Dairy Sci. 42:189.

Eusebio, A. N., J. C. Shaw, E. C. Leffel, S. Lakshmanan and R. N. Doetsch. 1959. Effect on rumen volatile fatty acids and rumen microbial dissimilation of glucose-C^{14} of corn meal when fed exclusively and in combination with hay or certain additives. J. Dairy Sci. 42:692.

Leatherwood, J. M., R. D. Mochrie and W. E. Thomas. 1960. Some effects of a supplementary cellulase preparation on feed utilization by ruminants. J. Dairy Sci. 43:1460.

Salsbury, R. L., C. K. Smith and C. F. Huffman. 1956. The effect of high levels of cobalt on the *in vitro* digestion of cellulose by rumen microorganisms. J. Animal Sci. 15:863.

Salsbury, R. L., A. L. VanderKolk, B. V. Baltzer and R. W. Luecke. 1958. The rates of digestion of the cellulose of some plant fractions by rumen microorganisms *in vitro*. J. Animal Sci. 17:293.

Shaw, J. C., R. R. Robinson, M. E. Senger, S. Lakshmanan and T. R. Lewis. 1959. Production of low-fat milk. I. Effect of quality and quantity of concentrate on the volatile fatty acids of the rumen and on the composition of the milk. J. Nutr. 69:235.

EVALUATION OF SUPPLEMENTAL LYSINE FOR PRACTICAL SWINE RATIONS

N. D. MAGRUDER, W. C. SHERMAN AND W. M. REYNOLDS

Chas. Pfizer & Co., Inc., Terre Haute, Indiana

THE essentiality of lysine in the nutrition of the pig was demonstrated initially by Mertz *et al.* (1949). A number of investigators subsequently have published results of determinations of lysine requirements. Brinegar *et al.* (1950), using three types of experimental rations, reported lysine requirements as 0.6% and 1.2% of total ration at respective protein levels of 10.6% and 22.0% for pigs of initial weight 30 to 43 lb., fed for 28 days. Meade (1956) found that the addition of L-lysine failed to improve nitrogen retention of 100-lb. pigs on a corn-soybean oil meal ration containing 15.9% protein and 0.69% lysine. Hutchinson *et al.* (1957) fed a semi-purified diet containing 11.69% protein to weanling pigs of 35 lb. initial weight for 21 days and found 0.52% lysine needed for optimum growth. Germann *et al.* (1958) reported 0.70% as the lysine requirement of 6 to 7-week-old pigs fed a semi-purified diet containing over 80% corn plus amino acids and other nutrients with a protein equivalent of 15% (moisture-free). McWard *et al.* (1959) found for 30-lb. pigs a lysine requirement of 0.71% on 12.8% protein and 0.95% on 21.7% protein. Feeding continued for 28 days. These workers used semi-purified diets containing corn starch, sesame seed meal and L-histidine.

In the present study, lysine supplementation of practical baby pig rations was investigated to determine whether, with less than conventional levels of protein but with added lysine, performance would approach that on conventional protein. Lysine supplementation of practical growing-finishing rations was investigated in two ways: (1) to determine whether low-protein corn-soybean oil meal and corn-soybean oil meal-alfalfa-meat and bone scrap rations plus lysine would bring about performance comparable to that of a conventional level of protein; and, (2) to determine effects of lysine supplementation of corn-peanut meal and milo-soybean oil meal rations. The pigs in the growing-finishing experiments were carried to market weight.

Experimental Procedure

Baby Pigs. A total of 64 hybrid baby pigs, weaned at 10 days, weighing approximately 8 lb., were allotted to four comparable treatment groups. They received a 26% protein corn-soybean oil meal-dried skim milk pre-starter until 21 days of age. During this stage there were two groups, one receiving 0.1% supplemental lysine and one serving as controls. At 21 days of age these pigs were changed to a corn-soybean oil meal-dried whey starter. There were two protein levels, 16% and 14%, each with and without 0.1% supplemental lysine, so that there were four treatment groups, each divided into four replicates. The low-protein ration was derived from the high-protein by lowering soybean oil meal and increasing corn.

The pigs which had received supplemental lysine in the pre-starter were allotted into lysine-supplemented groups on the starter. Table 1 shows composition of the pre-starter and starters. The calculated amount of lysine in the 16% protein basal starter was 0.87% and the 14% basal contained 0.74% lysine. The pigs remained on the experiment to 56 days of age. They were housed in heated rooms that were divided by diagonal partitions. Groups were assigned in such a way as to eliminate location effects.

Growing-Finishing Pigs. There were three trials with weanling pigs which were allotted to treatments by litter, body weight and sex. All were wormed with piperazine dihydrochloride prior to the start. Animals of trials 1 and 3 were on concrete and those of trial 2 were on dirt.

In trial 1, forty hybrid pigs of approximately 39 lb. initial weight were placed on corn-soybean oil meal, alfalfa-meat and bone scrap growing rations. There were two protein levels, 14% and 11%, each with and without supplemental lysine, so that there were four treatment groups. When the pigs reached 125 lb., protein levels were reduced from 14% to 12% and from 11% to 9%, with and without

lysine supplementation. Protein reduction was accomplished by substituting corn for soybean oil meal. The calculated percentages of lysine in the 14%, 12%, 11% and 9% unsupplemented basal rations were 0.64, 0.50, 0.42 and 0.30, respectively.

Trial 2 was similar to Trial 1, except that the difference between high- and low-protein basal rations was not as great. There were 64 weanling pigs assigned to four treatments with two replications of eight pigs on each. Two treatments comprised a 14% basal reduced to 12% at 125 lb., with and without 0.1% added lysine. The other two treatments comprised a 12.5% protein basal, reduced to 10.5% at 125 lb., with and without 0.1% added lysine. The compositions of the initial 14% and 12.5% protein basal rations appear in table 2.

In trial 3, sixty-four weanling hybrid pigs weighing approximately 50 lb. were allotted to four treatments with two replications of each. Milo-soybean oil meal and corn-peanut oil meal basal rations, shown in table 3, were fed as controls and with the addition of 0.1% lysine. Both basal rations contained initially 14% protein reduced to 12% at 125 lb. Lysine

TABLE 1. PRESTARTER AND STARTER RATIONS FED FROM 10 TO 56 DAYS

Ingredients	Prestarter	Starter	
		16%	14%
	lb.	lb.	lb.
Yellow corn meal	12.6	39.0	44.0
Soybean oil meal (50%)	17.5	....	....
Soybean oil meal (44%)	....	20.0	15.0
Dried skim milk	40.0	....	....
Dried whey (50%, delactosed)	3.0	10.0	10.0
Ground oats	....	10.0	10.0
Fish meal, menhaden	2.5	2.0	2.0
Dried brewers yeast	2.0	....	....
Stabilized animal fat	5.0	....	....
Sucrose	10.0	10.0	10.0
Cerelose	5.0	5.0	5.0
Limestone, ground	0.05	0.4	0.4
Dicalcium phosphate	0.25	1.6	1.6
Iodized salt	0.5	0.5	0.5
Trace mineral premix [a]	0.1	0.1	0.1
Vitamin premix [b]	1.0	1.0	1.0
TM-10 [c]	0.5	0.5	0.5
Lysine supplement carrier [d]	0.57	0.57	0.57
	100.57	100.67	100.67
Protein, %, (calculated)	26.4	15.7	13.9
Lysine, %, (calculated)	1.83	0.87	0.74

[a] Mineral premix supplied the following in ppm of complete rations: Fe, 74; Cu, 16; Co, 2; Mn, 36; Zn, 100.

[b] Contributed the following per pound of complete rations of all types: vitamin A, 5,000 I.U.; vitamin D, 1,020 I.U.; riboflavin, 5.0 mg.; niacin, 30.0 mg.; calcium pantothenate, 10.0 mg.; choline, 50.0 mg.; vitamin B_{12}, 20.0 mcg.; pyridoxine, 2 mg.; ascorbic acid, 300.0 mg.; thiamine, 5.0 mg.; folic acid, 8.0 mg.; menadione, 1.0 mg.

[c] Premix contains 10 gm. oxytetracycline (Terramycin) per lb. Level used supplied 50 mg. antibiotic per lb. of complete rations.

[d] Corn oil meal. In lysine-supplemented lots this carrier contained 80 gm. L-lysine per lb. to add 0.1% L-lysine to the complete ration.

TABLE 2. BASAL RATIONS FOR GROWING-FATTENING PIGS—TRIALS 1 AND 2

Ingredients	Trial 1		Trial 2	
	High protein	Low protein	High protein	Low protein
	lb.	lb.	lb.	lb.
Ground yellow corn	80.50	90.00	81.00	85.00
Solvent soybean oil meal	13.75	5.75	16.00	12.00
Meat and bone scraps	1.00	0.40	.....	.....
Dehydrated alfalfa meal	1.50	0.60	.....	.....
Steamed bone meal	1.00	1.00	1.00	1.00
Ground limestone	1.00	1.00	1.00	1.00
Iodized salt	0.50	0.50	0.50	0.50
Trace mineral premix [a]	0.25	0.25	0.25	0.25
Vitamin premix [b]	0.25	0.25	0.25	0.25
TM-10 [c]	0.10	0.10	0.10	0.10
Lysine supplement carrier [d]	0.57	0.57	0.57	0.57
	100.42	100.42	100.67	100.67
Protein, %, to 125 lb.	14.0	11.0	14.0	12.5
Lysine, %, to 125 lb.	0.64	0.42	0.71	0.49
Protein, %, after 125 lb. [e]	12.0	9.0	12.0	10.5
Lysine, %, after 125 lb.	0.50	0.30	0.55	0.44

[a] Supplied the following in ppm of complete ration: Fe, 22; Cu, 4; Co, 8; Mn, 36; Zn, 94.

[b] Contributed the following per lb. of 14% protein rations in both trials: vitamin A, 1000 I.U.; vitamin D, 300 I.U.; riboflavin, 2.5 mg.; niacin, 10.0 mg.; calcium pantothenate, 10.0 mg.; choline, 100 mg.; vitamin B_{12}, 6.0 mcg.

[c] Contains 10 gm. oxytetracycline (Terramycin) per lb. Level used supplies 20 gm. antibiotic per ton of complete ration.

[d] Corn oil meal. In lysine-supplemented lots this carrier contained 80 gm. L-lysine per lb., to add 0.1% L-lysine to the complete ration.

[e] Protein lowered after 125 lb. by reducing soybean oil meal and increasing corn. Protein and lysine values calculated.

TABLE 3. BASAL 14% MILO-SOYBEAN OIL MEAL AND CORN-PEANUT OIL MEAL RATIONS—TRIAL 3

Ingredients	Milo SBOM ration	Corn-POM ration
	lb.	lb.
Milo	87.00	.....
Ground yellow corn	.....	83.00
Solvent soybean oil meal	10.00	.....
Peanut oil meal (50%)	.....	14.00
Steamed bone meal	1.00	1.00
Ground limestone	1.00	1.00
Iodized salt	0.50	0.50
Trace mineral premix [a]	0.25	0.25
Vitamin premix [a]	0.25	0.25
TM-10 [a]	0.10	0.10
Lysine supplement carrier [a]	0.57	0.57
	100.67	100.67
Protein, %, to 125 lb.	14.0	14.0
Lysine, %, to 125 lb.	0.55	0.50
Protein, %, after 125 lb. [b]	12.0	12.0
Lysine, %, after 125 lb.	0.40	0.39

[a] Trace minerals, vitamins, antibiotic and L-lysine supplement and nature of carrier were the same as in trials 1 and 2 for growing-fattening pigs.

[b] Protein lowered after 125 lb. by increasing milo or corn and decreasing soybean oil meal or peanut oil meal. Protein and lysine values calculated.

contents of the basal 14% milo and peanut meal rations were 0.55% and 0.50%, respectively, and of the basal 12% rations 0.40% and 0.39%, respectively.

Four pigs per group were slaughtered at 200 lb. and the carcasses were split and chilled for 24 hours before measurements were taken. Backfat thickness was determined on the right side of the carcass at the first rib, 10th rib and last lumbar vertebra. Length of carcass was taken from the anterior edge of the first rib to the anterior edge of the aitch bone. Planimeter readings on the area of the *Longissimus dorsi* muscle were made from tracings taken at the 10th rib of the right side after cutting this muscle perpendicularly to the backbone. Dressing percent was based on shrunk live weight and cold carcass minus head.

Results and Discussion

Baby Pigs. Body weight gain and feed efficiency data are presented in table 4. There was a slightly higher rate of gain in the group which received 16% protein plus supplemental lysine when compared to the three other treatment groups. A portion of this effect was due to increased protein as will be noted from comparing gains on the 16% protein basal with those on the 14% protein basal. A significant increase in rate of gain ($P<.05$) resulted from adding lysine to the 14% protein starter which contained 0.74% lysine. The rate of gain with supplementation of this low level of protein was equal to that on the 16% protein starter not supplemented with lysine. Feed efficiency was improved but not to a significant degree in the group fed 14% protein

TABLE 4. EFFECT OF 0.1% SUPPLEMENTAL LYSINE ON GROWTH AND FEED EFFICIENCY OF BABY PIGS FED 14% AND 16% PROTEIN STARTERS

Ration description	16% Basal	16% Basal + lysine	14% Basal	14% Basal + lysine
Av. daily gain, lb.	0.71	0.75	0.61	0.71
Feed per lb. gain, lb.	2.06	2.04	2.24	2.15

Analysis of variance of average daily gains in baby pig experiment

Source of variance	d.f.	Mean square
Protein (P)	1	0.068*
Lysine (L)	1	0.077*
P x L	1	0.050
Litter	15	0.015
Error	44	0.013

* $P<.05$.

TABLE 5. EFFECT OF 0.1% SUPPLEMENTAL LYSINE ON GROWTH AND FEED EFFICIENCY OF GROWING-FINISHING PIGS FED OPTIMUM AND LOW-PROTEIN RATIONS—TRIALS 1 AND 2

Ration description	Basal	Basal + 0.1% lysine	Basal	Basal + 0.1% lysine
	Trial 1			
Protein, %, to 125 lb.	14	14	11	11
Protein, %, 125–210 lb.	12	12	9	9
No. of pigs	9	10	10	10
Initial wt., lb.	38.9	38.9	38.9	38.9
Final wt., lb.	212.9	210.6	158.2	178.3
Daily gain, lb.[a]	1.54	1.52	1.10	1.28
Feed per lb. gain, lb.	3.75	3.74	4.52	4.11
	Trial 2			
Protein, %, to 125 lb.	14	14	12.5	12.5
Protein, %, to 200 lb.	12	12	10.5	10.5
No. of pigs	16	15[b]	14[b, c]	16
Initial wt., lb.	33.7	33.8	33.7	33.7
Final wt., lb.	201.2	201.7	188.5	202.2
Daily gain, lb.	1.44	1.43	1.24	1.37
Feed per lb. gain, lb.	3.20	3.49	3.65	3.22

Analysis of variance—Trial 2

Source of variance	Average daily gain d.f.	Average daily gain Mean square	Feed per lb. gain d.f.	Feed per lb. gain Mean square
Protein (P)	1	0.245**	1	0.410
Lysine (L)	1	0.010	1	0.182
P x L	1	0.095*	1	8.010*
Litter	15	0.074*	..	.....
Error	42	0.023	4	0.721

[a] $P<.001$ and $P<.05$ for protein and lysine, respectively.
[b] Removed due to umbilical hernia.
[c] Died due to respiratory ailment.
** $P<.01$.
* $P<.05$.

plus lysine as compared with no supplemental lysine. Moreover, feed efficiency of both low-protein groups was somewhat below that of the two high-protein groups.

Growing-Finishing Pigs. Growth and feed efficiency results for trials 1 and 2 are shown in table 5 and growth, feed efficiency and carcass data from trial 3 are shown in table 6. In trial 1, pigs fed the unsupplemented 14%–12% corn-soybean oil meal ration gained significantly better ($P<.001$) than pigs fed the unsupplemented 11%–9% protein ration, a difference attributable to protein *per se*. Lysine had no effect on gains or feed efficiency at the normal protein level.

There was a significant improvement in rate of gain and an enhancement in feed efficiency when lysine was added to the low-protein (11%–9%) ration.

TABLE 6. EFFECT OF 0.1% SUPPLEMENTAL LYSINE ON GROWTH, FEED EFFICIENCY AND CARCASS CHARACTERISTICS OF GROWING-FATTENING PIGS FED 14% PROTEIN MILO-SOYBEAN OIL MEAL OR CORN-PEANUT OIL MEAL RATIONS—TRIAL 3

Ration description	Milo-soybean basal	Milo-soybean + 0.1% lysine	Corn-peanut basal	Corn-peanut + 0.1% lysine
Protein, %, to 125 lb.	14	14	14	14
Protein, %, 125–200 lb.	12	12	12	12
Daily gain, lb.	1.21	1.47	1.12	1.41
Feed per lb. gain, lb.	4.19	3.69	4.07	3.65
Carcass length, in.	29.1	30.4	29.9	30.1
Backfat thickness, in.	1.63	1.55	1.73	1.67
Loin area, sq. in.	3.22	3.66	3.22	3.43
Dressing percent	75.1	77.3	76.3	78.0

Analysis of variance

Source of variation	Av. daily gains d.f.	Av. daily gains Mean square	Feed per lb. gain d.f.	Feed per lb. gain Mean square	Loin area d.f.	Loin area Mean square
Ration (R) [a]	1	0.114	1	0.240	1	0.036
Lysine (L)	1	1.150***	1	7.60**	1	0.280*
R x L	1	0.014	1	0.030	1	0.035
Litter	15	0.142	..	.....	..	.....
Error	43	0.080	4	0.322	12	0.045

[a] Milo vs. peanut meal.
*** P<.001.
** P<.01.
* P<.05.

Trial 2 was designed with a smaller span between high- and low-protein basals in the belief that lysine supplementation of low protein might enhance performance to a level approximating that on high protein. In this trial, as in the previous, lysine brought about no improvement in rate of gain when added to a ration containing 14%–12% protein which is considered normal for pigs of this age. Also, paralleling trial 1, there was a difference in rate of gain due to protein *per se* between pigs fed the 14%–12% unsupplemented diet and those fed the unsupplemented 12.5%–10.5% protein diet. The addition of 0.1% lysine to the lower-protein (12.5%–10.5%) basal ration resulted in a significant increase in gain over no supplementation. Moreover, there was no significant difference in rate of gain between low protein plus lysine and high protein without lysine, although the gains on the lower protein were somewhat smaller numerically (1.37 lb. vs. 1.43 lb. per day).

The pigs on 12.5%–10.5% protein plus lysine exhibited better feed conversion than those on 14%–12% protein with lysine and about equal to that of those on high protein without lysine (3.22 vs. 3.20 lb.). An unexplained significant difference in feed efficiency in favor of no lysine occurred with 14%–12% protein.

In trial 3, the two 14%–12% protein basal rations were milo-soybean oil meal and corn-peanut meal. Milo contains only 0.28% lysine and peanut oil meal contains 1.28% lysine as compared with about 2.75% for soybean oil meal (N.R.C., 1953). As shown in table 6, 0.1% supplemental lysine increased rate of gain and feed conversion significantly on both rations. Table 6 also presents carcass data. With both basal rations, lysine supplementation brought about significant increases in loin area. Dressing percent was increased and backfat thickness decreased but not significantly. Because of the small number of animals, these findings should be regarded as preliminary.

These findings are consistent with those of Brooks and Thomas (1959) who found that addition of 0.5% or 0.3% lysine to peanut meal-corn rations produced highly significant improvements in rate of gain and muscle development.

Summary

Experiments were conducted to test the effect of 0.1% supplemental lysine with baby pig rations of conventional composition and with growing-finishing rations based on corn-soybean oil meal, sorghum-soybean oil meal, and corn-peanut oil meal. Baby pigs on a 14% protein starter with added lysine grew at a rate equal to that of pigs on the basal 16% starter. In growing-finishing trial 1, the basal corn-soybean oil meal rations contained 14% protein, reduced to 12% at 125 lb. and 11% reduced to 9% at 125 lb. On the lower protein level, added lysine improved growth and feed efficiency, but it did not occur on the higher "normal" protein. In trial 2, with corn-soybean oil meal ration and protein levels of 14%–12% and 12.5%–10.5%, 0.1% added lysine significantly improved gain on the lower protein level so that the rate almost equaled that of the lot which received unsupplemented 14%–12% protein. However, lysine supplementation of a 14%–12% protein ration did not improve performance. Pigs on 12.5%–10.5% protein plus lysine exhibited better feed efficiency than those on 14%–12% protein with lysine and in this respect were about

equal to those on the higher protein without lysine.

In trial 3, with low-lysine milo-soybean oil meal or corn-peanut oil meal rations containing 14%–12% protein, supplemental lysine (0.1%) significantly increased rate of gain and feed efficiency on both rations. There was a tendency toward improvement of some carcass characteristics in lysine-fed pigs of trial 3.

Literature Cited

Brinegar, M. J., H. H. Williams, F. H. Ferris, J. K. Loosli and L. A. Maynard. 1950. Lysine requirement for growth of swine. J. Nutr. 42:129.

Brooks, C. C. and H. R. Thomas. 1959. Supplements to peanut oil meal for growing fattening swine. J. Animal Sci. 18:1119.

Germann, A. F. O. II, E. T. Mertz and W. M. Beeson. 1958. Re-evaluation of L-lysine requirement of weanling pigs. J. Animal Sci. 17:52.

Hutchinson, H. D., A. H. Jensen, S. W. Terrill and D. E. Becker. 1957. The lysine requirement of the weanling pig. J. Animal Sci. 16:558.

McWard, G. W., D. E. Becker, H. W. Norton, S. W. Terrill and A. H. Jensen. 1959. The lysine requirement of weanling swine at two levels of dietary protein. J. Animal Sci. 18:1059.

Meade, R. J. 1956. The influence of tryptophan, methionine and lysine supplementation of a corn and soybean oil meal diet on nitrogen balance of growing swine. J. Animal Sci. 15:288.

Mertz, E. T., D. C. Shelton and W. M. Beeson. 1949. The amino acid requirement of swine, lysine. J. Animal Sci. 8:524.

N.R.C. 1953. Nutrient requirements for domestic animals. No. 2. Nutrient requirements for swine. National Research Council, Washington, D. C.

EFFECT OF OLEANDOMYCIN ON FATTENING AND SUCKLING LAMBS [1]

R. M. JORDAN AND H. E. HANKE

University of Minnesota, St. Paul

MANY lamb feeders use oxytetracycline or chlortetracycline as a means of increasing rate of gain and feed efficiency and of minimizing death loss due to overeating disease. However, in controlled experiments there has been inconsistency in the response obtained from feeding these antibiotics (Jordan *et al.*, 1956). Results of several lamb fattening experiments involving the antibiotic, oleandomycin, have been reported by Hale *et al.* (1960). They reported that fattening lambs fed 2 gm. of oleandomycin per ton of ration outgained the control lambs 9.6% and that 6 gm. of oleandomycin per ton of ration increased gains 18.9%. Fifteen grams per ton of either oxytetracycline or oleandomycin reduced substantially the number of cases of urinary calculi.

The purpose of the present experiments was to study the effect of oleandomycin on both fattening lambs and suckling lambs.

Procedure

The 70 native lambs used in the fattening experiments were sheared prior to the start of the experiment. They were hand-fed shelled corn, long alfalfa-bromegrass hay of good quality and protein supplement twice daily. A mixture of 2 parts of trace mineralized salt and 1 part bone meal was offered free choice. Oleandomycin was incorporated into the soybean oil meal and fed at a rate of 5 mg. per lamb daily in Experiment 1 and 10 mg. per lamb daily in Experiments 2 and 3. The lambs were allotted at random into treatment groups from outcome groups based upon weight and sex.

Experiments 4, 5, 6 and 7 were conducted with 198 suckling lambs obtained from the station flock. Prior to the experiments the lambs were fed a standard creep ration so that they were accustomed to eating at the time they were placed on test at 3 to 4 weeks of age. They were allotted at random into treatments from outcome groups based on weight, breed, sex and type of birth (single or twins). In each experiment oleandomycin was incorporated into the ration at a level of 10 mg. per pound of total ration. The ration was kept in front of the lambs at all times; however, the feed bunks were cleaned out daily to prevent accumulation of stale and unpalatable feed. In Experiments 4 and 6 a ground creep ration was fed, and in Experiments 5 and 7 a pelleted creep ration. The ewes suckling the lambs were fed 5–6 lb. of legume hay and 1–1.5 lb. of shelled corn per head daily. All lambs were individually weighed at the start of each experiment and approximately every 14 days thereafter.

Results and Discussion

Treatment, rate of gain, feed consumption and feed efficiency, along with data pertaining to cause of death in all experiments are presented in table 1.

Fattening Lambs. Oleandomycin, at the level of 5 mg. per lamb daily, had no effect on average daily gain, feed consumption, feed efficiency or death loss.

Lambs fed 10 mg. oleandomycin daily gained about 13% faster than the controls in both Experiments 2 and 3. When the gain data from Experiments 2 and 3 were combined and analyzed, the difference between the control and treated lambs was significant at the 5% level. Feed consumption by the two groups was similar; and, because of greater gain, the antibiotic-fed lambs required less feed per pound of gain. Three lambs died from enterotoxemia, two in the control group and one in the treated group.

Hale *et al.* (1960) obtained faster gains and greater feed efficiency from feeding 6 gm. than from 2 gm. of oleandomycin per ton of feed. Based on feed consumption reported in their experiment, 2 gm. of oleandomycin per ton provided about 7 to 10 mg. per lamb daily. Thus it is suggested that 5 mg. of oleandomycin per lamb daily are not enough to increase gains of fattening lambs.

Suckling Lambs. Suckling lambs fed 10 mg.

[1] Paper No. 4478, Scientific Journal Series of the Minnesota Agricultural Experiment Station, St. Paul.

TABLE 1. EFFECT OF OLEANDOMYCIN ON FATTENING AND SUCKLING LAMBS

Treatment	No. lambs	Av. initial weight	Av. daily gain	Gain index[a]	Daily feed	Feed/ gain	Death loss: Entero-toxemia	Death loss: Calculi
		lb.	lb.	%	lb.	lb.		
				Experiment 1—50 days				
Basal	13	74.6	0.52	100	3.44	6.61	0	..
Oleandomycin, 5 mg. per lamb daily	13	74.9	0.52	100	3.36	6.43	0	..
				Experiment 2—42 days				
Basal	8	67.5	0.45	100	3.18	7.11	0	..
Oleandomycin, 10 mg. per lamb daily	8	66.5	0.51	113.3	3.20	6.21	0	..
				Experiment 3—56 days				
Basal	14	78.1	0.39	100	3.33	8.52	2	..
Oleandomycin, 10 mg. per lamb daily	14	75.5	0.46	117.9	3.26	7.02	1	..
				Experiment 4—52 days				
Basal, meal	26	18.0	0.59	100	0.61	1.03	..	0
Oleandomycin, 10 mg. per lb. ration	26	19.2	0.66	111.9	0.78	1.19	..	0
				Experiment 5—52 days				
Basal, pellets	28	18.3	0.71	100	0.83	1.32	..	2
Oleandomycin, 10 mg. per lb. ration	28	18.6	0.82	115.5	0.91	1.33	..	2
				Experiment 6—52 days				
Basal, meal	27	18.4	0.65	100	0.57	0.94	..	1
Oleandomycin, 10 mg. per lb. ration	27	17.3	0.72	110.7	0.81	1.15	..	2
				Experiment 7—50 days				
Basal, pellets	18	21.6	0.75	100	1.19	1.59	..	0
Oleandomycin, 10 mg. per lb. ration	18	22.6	0.82	109.3	1.21	1.48	..	0

[a] Gain index based on basal as 100% in each experiment.

of oleandomycin per pound of ration gained faster than control lambs in each of four experiments. When the data of the four experiments were pooled and analyzed, the difference in average daily gain between the control lambs and the treated lambs was significant at the 5% level. In three of the four experiments, creep feed consumption by lambs in the treated lots was appreciably greater than in the control lots. This increased feed consumption, while not statistically significant, may account for the increased gains. In Experiment 6 lambs fed oleandomycin consumed approximately 42% more than the controls. This high feed consumption resulted in less feed efficiency.

During Experiments 5 and 6, seven of the lambs died from urinary calculi. Three lambs were in the control groups and four were in the treated groups. These lambs had a particular liking for the trace mineralized salt-bone meal mixture supplied the ewes free choice. Their ration contained 0.5% dialcium phosphate, and this relatively high phosphorus intake may explain the high incidence of urinary calculi in lambs 4–6 weeks of age. Contrary to the report of Hale *et al.* (1960), oleandomycin gave no protection from urinary calculi.

Summary

Three lamb fattening experiments and four experiments involving suckling lambs were conducted to determine the effect of feeding oleandomycin on average daily gain, feed consumption and feed efficiency.

Five mg. of oleandomycin per lamb daily showed no effect on gain of fattening lambs or feed required per pound of gain. Ten mg. of oleandomycin increased average daily gain about 15% and feed efficiency about 20%.

Oleandomycin did not give fattening lambs complete protection against enterotoxemia.

Oleandomycin increased average daily gain of suckling lambs in all four experiments and increased feed consumption in three. It did not appear to give any protection against urinary calculi in young suckling lambs.

Literature Cited

Hale, W. H., W. C. Sherman, H. G. Luther and W. M. Reynolds. 1960. Evaluation of oleandomycin in lamb fattening rations. J. Animal Sci. 19:590.

Jordan, P. S., R. M. Jordan and H. G. Croom. 1956. Effect of chlortetracycline, stilbestrol and chlortetracycline-stilbestrol supplements on fattening lambs. J. Animal Sci. 15:188.

RELATION OF FORAGE NUTRIENT DIGESTIBILITIES TO VARIED HAY-GRAIN RATIOS

E. A. KANE, W. C. JACOBSON AND L. A. MOORE [1]

Animal Husbandry Research Division, ARS, Agricultural Research Center
Beltsville, Maryland

MITCHELL (1943) was of the opinion that the roughage-concentrate mixture had an effect on the protein digestibilities of feed, but the effect was largely unpredictable. Watson *et al.* (1947), after several well-documented experiments, detected no effects on protein digestibilities from feeding different mixtures of hays and concentrates. Phillips *et al.* (1951) reported that the apparent digestibility of the nutrients, as well as intake energy, usually increased as the grain percent of the ration rose. Dowe and associates (1955) claimed that no significant differences in nutrient digestibilities occurred when equal levels of digestible protein were fed. Elliot and Loosli (1959) have reported that neither protein nor crude fiber digestibility was affected by changes in hay-concentrate ratios. Putnam and Loosli (1959) stated that digestibility coefficients (excepting crude fiber) increase as the proportion of concentrates increased, and within the range investigated (0 to 60% grain) no change in nutrient digestibilities was found that could not be explained by the additive digestibilities of roughages and concentrates fed. Dowden *et al.* (1959) found that the feeding of grain at three levels (0, 6, and 12 lb/day) had no apparent effect on the forage dry matter digestibility, when rations were corrected for the grain fed by assuming a constant digestibility for the grain.

Since, in most of the previously conducted experiments, using varying hay-grain ratios, the net energy intake was not equalized, the present experiment was carried out so that the energy would remain relatively constant.

Experimental Procedure

The experiment involved a Latin square design in which six cows were fed three grain levels in three periods. Based on estimated net energy content the hay-grain ratios were approximately 1:1, 3:1 and 10:1. On a dry matter basis the grain percent of the rations averaged 36.5, 16.4 and 6.6%, respectively. Digestibilities were determined by the chromium oxide ratio technique with partial collection of feces. Two fecal samples were taken daily, between 5 and 7 a.m. and 12:30 and 2:30 p.m. Cows were fed at 5:00 a.m. and 1:30 p.m. Chromium oxide, in the amount of 15 gm. daily, premixed with 85 gm. wheat flour, was blended into the cows' grain allotment at each feeding. Collection periods were 5 days in length; preliminary periods were 9 days.

A 2-day lag was allowed for the passage of food through the animals. Both Moore and Winter (1934) and Balch (1951) clearly demonstrated that considerable variation existed among bovines in the rate of voiding food residues. Balch's data indicated that the first 10% of the food residues required 22 to 39 hours to be eliminated, while 80% were excreted in 70–90 hours. If these conditions prevail, collection periods between 48 and 72 hours would contain less error than a 24 to 48-hour period.

The hay used had been graded U.S. No. 1. It was purchased commercially and averaged 18.8% protein content. Grain fed was a mixture of corn meal 40, wheat bran 20, crushed oats 20, soybean oil meal 40, and iodized salt 1.

Dry cows were used, two holsteins and four Jerseys. The animals were fed individually in concrete mangers, receiving for maintenance amounts of estimated net energy between Morrison's recommended minima and the higher amounts advised under usual conditions. Cows ate the high grain ration rapidly and appeared to desire more food after their allotment had been consumed. More orts were observed with the low grain ration. The total feed refused for the three periods (from high to low grain levels) were: 12, 127 and 187 gm., respectively, on a dry matter basis.

All hay bales fed were sampled by boring. Daily samples of grain, feces, and refused feed were taken and composited for the period. Daily fecal samples were dried under

[1] The authors gratefully acknowledge the technical assistance of O. M. Bowman and P. M. Damewood, Jr.

TABLE 1. COMPOSITION OF FEEDS INCLUDING ENERGY CONTENT (DRY BASIS)

Feed	Period	C.P.[a]	C.F.	Ash	E.E.	N-F.E.	T.D.N.	C.N.E.
				%				Therms per cwt.
Alfalfa hay	1	18.3	24.1	11.2	2.20	44.1	55.9[b]	43.2
Alfalfa hay	2	18.9	26.1	9.8	2.15	43.0	55.8[b]	43.1
Alfalfa hay	3	19.1	24.7	10.9	2.25	43.0	55.1[b]	42.1
Average		18.8	25.0	10.6	2.20	43.4	55.6	42.8
Grain	1	26.2	6.74	5.75	3.58	57.8	84.8[c]	83.5
Grain	2	26.0	6.56	5.61	3.17	58.7	84.8[c]	83.5
Grain	3	26.0	7.17	5.31	2.64	58.9	84.8[c]	83.5
Average		26.1	6.82	5.57	3.13	58.5	84.8	83.5

[a] C.P.=crude protein; C.F.=crude fiber; E.E.=ether extract; N-F.E.=nitrogen-free extract; T.D.N.=total digestible nutrients; C.N.E.=calculated net energy (regression formula of Moore *et al.*, 1953).
[b] Determined experimentally.
[c] Calculated from Morrison values.

forced draft at 80° C. to constant weight prior to combining. Quadruplicate proximate analyses of feed and fecal samples were carried out by methods of the Association of Official Agricultural Chemists (A.O.A.C., 1955). Chromium oxide analyses were made by the method of Christian and Coup (1954), modified to handle samples containing up to 35 mg. chromium oxide. Original method limits sample chromium oxide content to 15 mg. By increasing the recommended 3 ml. of both the phosphoric acid-manganese sulphate mixture and the bromate solution used in the first treatment of the ashed samples to 6 ml. and adding 3 instead of 1 ml. bromate solution in the final oxidation, it was found that ashed samples of 5–6 gm. air dried feces of around 0.5% chromium oxide content could be accurately determined. Statistical procedures used were analyses of variance, regression, and correlation.

Results and Discussion

Chemical analyses of the hay and grain fed are shown in table 1. The protein content of both hay and grain was high so that the nutritive ratio of the rations averaged 1:3.0. While the rations fed were relatively constant in energy intake and digestible protein, the dry matter intake varied progressively from the highest to the lowest grain level in the following manner: 1.00, 1.12 and 1.21.

Average ration component digestibilities are shown in table 2. Ration digestibilities of dry matter, crude protein, ether extract, and nitrogen-free extract at the 36% grain level were significantly ($P<1\%$) higher than the other levels. Between the 16 and 7% grain levels, crude protein, ether extract, and nitrogen-free extract digestibilities showed significant differences at the 5% level. These results are in agreement with other workers (Dowe *et al.*, 1955; Elliot and Loosli 1959; Phillips *et al.*, 1951; Putnam and Loosli, 1959), who have shown higher nutrient digestibilities with increased grain levels.

In this experiment the digestibility of the forage components was determined by two methods. The first method was done by subtracting from the fecal component (obtained by chemical analyses of the feces from the hay-grain mixtures fed) the indigestible residues of the grain components as given in table 1 of Morrison (1956). Indigestibilities were

TABLE 2. AVERAGE DIGESTIBILITY COEFFICIENTS OF NUTRIENTS (6 COWS)

% Grain in ration	D.M.	C.P.	C.F.	Ash	E.E.	N-F.E.
Total ration						
7	62.5	74.0	39.9	44.4	33.0	74.2
16	63.3	74.7	39.8	42.4	36.0	75.5
36[a]	68.1	78.7	40.2	45.7	46.9	79.6
Forage						
7	60.9	72.1	41.2	47.8	22.4	72.3
16	59.7	71.2	38.7	47.5	23.7	72.2
36[a]	59.4	71.1	37.2	46.5	20.8	72.3

[a] Digestibility data of one cow discarded, since, except for E.E., deviations exceeded 4 times the average deviation of the remaining cows (Pierce and Haenisch, 1952).

TABLE 3. REGRESSION AND CORRELATION OF COMPONENT DIGESTIBILITIES ON POUNDS OF GRAIN FED DAILY (DRY BASIS)

Component	d.f.	Regression equation	St. error of estimate	Correlation coefficient
Dry matter	15	Y=60.6+0.382 X	1.25	0.90**
Crude protein	15	Y=72.3+0.315 X	0.91	0.92**
Crude fiber	15	Y=40.4—0.009 X	2.94	—0.02
Ash	15	Y=43.4+0.139 X	6.01	0.15
Ether extract	15	Y=26.5+1.022 X	6.24	0.74**
Nitrogen-free extr.	15	Y=72.9+0.317 X	1.41	0.83**

** Significant at the 1% level.

found by substracting the nutrient digestibility coefficients from 100.

Average forage component digestibilities for the three levels of grain are reported in table 2. No significant difference in any forage component digestibility was found for the grain levels fed. It is evident from a comparison of tables 2 and 3 that the significant differences obtained in ration digestibility components were due to the amounts of grain fed. The data indicate that no effect of grain and hay is likely to occur within the limits (7 to 36% grain), when the net energy and high protein level of the ration are kept fairly constant.

The second method of determining forage component digestibility was from linear regression equations of ration component digestibilities. Regression equations for the component digestibilities are shown in table 3. The Y-intercept, or the zero grain values of these equations, represent estimated values for the forage component digestibilities by the regression method. The two methods were found to be in excellent agreement, as shown in table 4, with the exception of ash and ether extract digestibilities.

It was noted that the standard deviations from regression of ash and ether extract digestibilities were much higher than those of the other nutrients (table 3). The high ash deviations may be due to the fact that since Morrison provided no data for ash digestibilities, the assumption of 50% ash digestibility by the authors may not have been an accurate estimate. The high ether extract deviations from regression may be due to the low ether extract content of the feeds and feces, approximately 2 and 4%, respectively. These low values would tend to magnify the effect of analytical errors on digestibility determinations.

The highly significant correlations, shown in table 3, were found between the dry matter, protein, ether extract, and nitrogen-free extract digestibilities and the amounts of grain fed. Correlation results lend additional support to the finding that the significant ration component digestibility differences were due solely to differences in amounts of grain fed.

The TDN of the alfalfa hay that was fed was measured experimentally by correcting for the grain that was fed. The average TDN on a dry basis was 55.6. Morrison reports alfalfa hay with similar crude fiber content at 57.6 TDN.

Summary

Seventeen individual cow digestion trials were carried out, to study the effect of varied hay-grain intakes on forage component digestibilities. Estimated net energy intake was kept relatively constant. The plan of the experiment involved a Latin square. The approximate levels of grain fed in the rations were: 7, 16 and 36%, on a dry matter basis.

While significant increases in ration component digestibilities were observed, no effect associated with hay-grain ratios was established, since the forage component digestibilities (ration corrected for grain) showed no significant differences for grain levels.

The calculation of forage component digest-

TABLE 4. AVERAGE COMPONENT DIGESTIBILITIES OF ALFALFA HAY CALCULATED BY TWO METHODS

Method	Dry matter	Crude protein	Crude fiber	Ash	Ether extract	Nitrogen-free extract
By regression	60.6	72.3	40.4	43.4	26.5	72.9
Conventional	60.0	71.5	39.0	47.3	22.3	72.3

ibilities in mixed hay-grain rations can be performed satisfactorily either by correction of fecal component quantities for the amounts of indigestible material in the grain fed or by regression of component digestibilities on the amounts of grain fed.

Regression of ration component digestibilities on amounts of grain fed (1–5 lb. daily) are shown.

A modification of the Christian-Coup chromium oxide method is provided, whereby the originally imposed limit of chromium oxide content in sample can be raised from 15 to 30 mg. without loss of accuracy.

Literature Cited

A.O.A.C. 1955. Official Methods of Analysis (8th ed.). Association of Official Agricultural Chemists. Washington, D. C.

Balch, C. C. 1951. Factors affecting the utilization of food by dairy cows. I. The rate of passage of food through the digestive tract. Brit. J. Nutr. 4:361.

Christian, K. R. and M. R. Coup. 1954. Measurement of feed intake by grazing cattle and sheep. VI. The determination of chromic oxide in faeces. New Zealand J. Sci. Tech. A. 36:328.

Dowden, D. R., D. M. Seath, B. F. Brown and D. R. Jacobson. 1959. A comparison of zero, moderate and liberal levels of grain feeding for lactating cows in permanent, improved and supplemented pasture. J. Dairy Sci. 42:1960.

Dowe, T. W., J. Matsushima and V. Arthaud. 1955. The effects of the corn-alfalfa hay ratio on the digestibility of the different nutrients by cattle. J. Animal Sci. 14:340.

Elliot, J. M. and J. K. Loosli. 1959. Effect of the dietary ratio of hay to concentrate on milk production, ration digestibility, and urinary energy losses. J. Dairy Sci. 42:836.

Mitchell, H. H. 1943. Biological methods of measuring the protein value of feeds. J. Animal Sci. 2:264.

Morrison, F. B. 1956. Feeds and Feeding (22nd ed.). The Morrison Publishing Co., Ithaca, New York.

Moore, L. A., H. M. Irvin and J. C. Shaw. 1953. Relationship between TDN and energy value of feeds. J. Dairy Sci. 36:93.

Moore, L. A. and O. B. Winter. 1934. Rate of passage of inert materials through the digestive tract of the bovine. J. Dairy Sci. 17:297.

Phillips, C. A., S. D. Hardin and W. E. Thomas. 1951. The effect of corn-alfalfa hay ratio on the digestibility of the different nutrients by sheep. J. Animal Sci. 10:424.

Pierce, W. C. and Haenisch, E. L. 1952. Quantitative Analysis. p. 52. John Wiley and Sons, Inc., New York.

Putnam, P. A. and J. K. Loosli. 1959. Effect of feeding different ratios of roughage to concentrate upon milk production and digestibility of the ration. J. Dairy Sci. 82:1070.

Watson, C. J., J. W. Kennedy, W. M. Davidson, C. H. Robinson and G. W. Muir. 1947. Digestibility studies with ruminants. X. Relative associate effects of roughages, timothy and alfalfa, with barley. Sci. Ag. 27:4.

EFFECT OF FINISHING RATIONS ON GAINS, FEED EFFICIENCY AND CARCASS CHARACTERISTICS OF SWINE [1, 2]

D. L. HANDLIN, J. R. ABLES, D. H. KROPF AND R. F. WHEELER

South Carolina Agricultural Experiment Station, Clemson

SOUTH CAROLINA produces more livestock than can be finished to market weight on the amount of corn produced in the state. It may be feasible to grow such crops as oats, barley or grain sorghums if these grains can be used profitably in swine finishing rations without adversely affecting carcass characteristics. Research workers have conducted a number of experiments to estimate the relative feeding value of different grains in swine rations, but information on the effect of these grains on carcass characteristics is limited.

Wilson and Wright (1931) reported that barley was worth 95% of corn when fed to hogs in drylot. The carcasses from the hogs fed barley were found to be similar to those from the corn-fed hogs.

Fletcher (1953), Loeffel (1957), and Peo and Hudman (1958) reported that grain sorghums and corn produced approximately the same average daily gains, but, in general, 8 to 20% more feed was required per pound of gain with the grain sorghum.

Recent work was conducted by Jensen *et al.* (1959) to evaluate finely ground oats as a replacement for ground yellow corn in a corn-soybean oil meal ration. They concluded that replacing corn with oats in a corn-soybean oil meal ration tended to reduce rate of gain and feed efficiency. Hochstetler *et al.* (1959) found no significant difference in feed-lot performance or carcass characteristics among groups of hogs fed rations containing 0, 20 and 40% oats as a replacement for an equal proportion of corn.

The experiment reported herein was conducted to estimate the effect of various grains in swine rations on the average daily gain, feed required per pound of gain, and the effect of these rations on detailed carcass characteristics.

[1] Data from thesis submitted by J. R. Ables in partial fulfillment of the requirements for the Degree of Master of Science.

[2] Technical Contribution No. 346. South Carolina Agricultural Experiment Station. Published by permission of the Director.

Experimental Procedure

Three feeding trials were conducted at the Swine Research Center in the fall and winter of the years 1956–57, 1958–59 and 1959–60. Forty-nine fall-farrowed pigs were fed each year (total, 147). The pigs were individually self-fed in concrete-floored pens. Straw was used for bedding in the portion of the pen under shelter and the pens were cleaned twice weekly. Water was supplied to the pigs twice daily.

The breeds represented were Berkshire, Duroc, Hampshire, Poland China and Yorkshire. No more than three breeds were used in any one year. The pigs were raised on pasture until weaning at 8 weeks of age. They were treated for cholera, castrated and wormed with a piperazine compound before being put on test.

The pigs were placed on experiment at an average weight of 69 lb. Pigs were allotted to the seven treatments with litter, sex and weight balanced among treatments. The pigs were weighed individually at the beginning and end of the test and every 14 days throughout the experiment.

Seven treatments were repeated each year for 3 years. The grain portions of the concentrates fed in the seven treatments were: corn, barley; ½ corn ½ barley; milo; ½ corn ½ milo; ½ corn ½ oats; and ¾ corn ¼ oats. For simplification throughout this paper the treatments will be referred to as lot numbers 1, 2, etc. When a particular grain is mentioned, it will be in reference to the grain portion of the ration being fed.

The grains were ground through a 1/16 in. mesh screen and then mixed with the supplement. The protein supplement was a mixture of 50% fish meal, 25% alfalfa meal and 25% soybean oil meal. The rations were balanced according to the Morrison Standard. One percent calcite ($CaCO_3$) and 0.5% trace mineralized salt were added to each ration. The pigs were fed a 16% protein ration until the average weight of the lot reached 100 lb., a

14% protein ration from 100 to 150 lb., and from 150 lb. to market weight they were fed a 12% protein ration.

Individual hogs were weighed off test when they reached a live weight of approximately 200 lb. Feed was removed from the pen, but the hogs were allowed access to water for 24 hours. The hogs were then transferred to the Meat Research Laboratory and held for about 3 hours after which an empty slaughter weight was obtained. The loss in weight while held off feed, calculated as percent of full weight, is reported as percent drift. Dressing percent was calculated on the basis of empty slaughter weight. Both hot and cold carcass weight included weight of head and leaf fat.

Chilled carcass weight was determined after a 24-hour chill at 34° to 38° F. Carcass cooler shrink is reported as difference between hot and cold dressing percent. After a 48-hour chill, physical measurements were taken and standard cuts were made as recommended (with slight modifications) by the Reciprocal Meat Conference (1952) Pork Carcass Committee. Backfat samples were removed opposite the last lumbar vertebra and freezer stored until analyzed by the Hanus Iodine Number Method.

The data presented in this experiment were subjected to analysis of variance. Duncan's (1955) Multiple Range Test was used to determine which treatment differences were significant.

Results and Discussion

A summary of the feed-lot and slaughter data is presented in table 1. The control lot (corn) had the highest average daily gain of all the treatments. These gains were significantly higher than for those fed barley, milo or ½ corn ½ oats. Hogs fed barley made significantly slower daily gains than all treatments except those fed milo and ½ corn ½ oats. These results are not in agreement with those reported by Crampton *et al.* (1940), who stated that pigs fed barley gained slightly faster than those fed corn. Perhaps the barley grown in the Southeastern United States is not of the same quality as that grown in Canada. When barley and corn were fed in equal amounts (lot 3), there was no significant difference in average daily gain between this treatment and those fed corn.

Fletcher (1953) reported no significant difference in average daily gains of hogs fed milo or corn as the grain portion of the ration. When milo and corn were fed in equal amounts, there was no significant difference in rate of gain between the basal ration and the ½ corn ½ milo ration. Similar results were reported by Peo and Hudman (1958).

Apparently, oats could be used to replace up to 25% of the corn in a ration for finishing swine without seriously decreasing average daily gains in this test. Similar results were reported by Hochstetler *et al.* (1959).

TABLE 1. COMPARISONS OF GAIN, EFFICIENCY, DRIFT, DRESSING PERCENT AND CARCASS SHRINKAGE IN LOTS WITH DIFFERENT FEED GRAINS IN THE RATION [a]

Days on test	(1) [b] 73.8	(3) 74.9	(7) 76.2	(5) 77.6	(6) 81.8	(4) 82.0	(2) 88.1
Daily gain, lb.	(2) 1.55	(6) 1.64	(4) 1.69	(3) 1.80	(5) 1.80	(7) 1.80	(1) 1.87
Feed/lb. gain, lb.	(1) 3.37	(4) 3.72	(7) 3.74	(3) 3.77	(5) 3.82	(6) 4.04	(2) 4.48
Feed/day, lb.	(4) 6.20	(1) 6.26	(6) 6.57	(7) 6.70	(5) 6.72	(3) 6.74	(2) 6.82
Drift, % [c]	(1) 4.64	(5) 4.78	(4) 4.86	(2) 5.03	(6) 5.52	(7) 5.55	(3) 6.22
Chilled dressing % [d]	(2) 79.71	(3) 80.99	(1) 81.10	(6) 81.31	(4) 81.39	(7) 81.51	(5) 81.54
Carcass cooler shrink, %	(1) 1.59	(6) 1.68	(5) 1.69	(7) 1.73	(4) 1.75	(2) 1.76	(3) 1.80

[a] Any lot means not underlined by the same line are significantly different at the 5% level. A total of 21 pigs were used per treatment.
[b] Lot numbers: (1) corn, (2) barley, (3) ½ corn ½ barley, (4) milo, (5) ½ corn ½ milo, (6) ½ corn ½ oats, (7) ¾ corn ¼ oats.
[c] Drift reported as loss in weight as % of full weight.
[d] Based on empty slaughter weight and chilled carcass weight obtained after 24 hr. at 34°–38° F. Head and leaf fat included in carcass weight.

The control lot required an average of 3.37 lb. of feed per pound of gain. This was significantly lower than that required in lots 2 (barley), 5 (½ corn ½ milo), and 6 (½ corn ½ oats). The pigs on barley required an average of 4.48 lb. of feed per pound of gain. This was significantly higher than all treatments compared except lot 6 (½ corn ½ oats).

These data indicate that it takes approximately 10% or 0.3 to 0.4 lb. more feed to produce a pound of gain with milo than with corn. Similar results were reported by Fletcher (1953), Loeffel (1957) and Peo and Hudman (1958).

There were no significant differences among any of the treatments in the average amount of feed consumed per day.

The slaughter data are listed in table 1. No significant differences were found with regard to percent drift and percent carcass cooler shrink. Results indicate the cold dressing percent of the barley lot to be significantly lower than all other treatments.

Carcass physical measurements are presented in table 2. The average specific gravity of the carcasses from the animals fed barley was the highest of all treatments; however, lot 2 (barley) and lot 4 (milo) were the only two treatments significantly different in regard to carcass specific gravity. The carcasses from the milo-fed hogs tended to show a lower carcass specific gravity, indicating greater fatness. Brown *et al.* (1951) stated that the fat content of the carcass may be as accurately estimated by the specific gravity as by the percent of fat or lean cuts.

No significant difference was found with regard to ham specific gravity. Results of this experiment indicate that if treatment differences actually existed, then ham specific gravity did not show these differences. Pearson *et al.* (1956) reported that the specific gravity of either the entire carcass or a single untrimmed ham proved to be superior to backfat thickness as a measure of carcass leanness.

The carcasses from the animals fed barley had significantly less backfat (average of 3 measurements) than those from the hogs in lots 1 (corn), 4 (milo), 5 (½ corn ½ milo), and 7 (¾ corn ¼ oats). Perhaps this can be explained in this test by the slower gains of hogs fed barley. The carcasses from the hogs fed barley were significantly longer than those from the hogs fed milo.

Measurements of the loin eye area indicate that the carcasses from the barley-fed hogs had significantly more loin eye area than those fed milo or ½ corn ½ oats. Kline and Hazel (1955) and Zobrisky (1959) found a significant correlation between loin eye area and percent lean cuts. The mean percent of lean cuts from the barley-fed hogs tended to be the highest of all treatments but was significantly higher only when compared to the groups fed milo or ½ corn ½ milo.

TABLE 2. COMPARISON OF THE CARCASS DATA FROM LOTS WITH DIFFERENT FEED GRAINS IN THE RATION[a]

Carcass specific gravity	(4)[b] 1.039	(1) 1.041	(5) 1.041	(6) 1.041	(7) 1.041	(3) 1.042	(2) 1.045
Ham specific gravity	(4) 1.055	(5) 1.055	(6) 1.055	(7) 1.055	(1) 1.056	(3) 1.057	(2) 1.058
Backfat thickness, in.[c]	(2) 1.27	(3) 1.40	(6) 1.40	(7) 1.46	(1) 1.47	(5) 1.47	(4) 1.53
Carcass length, in.	(4) 28.9	(5) 29.0	(6) 29.0	(3) 29.2	(7) 29.2	(1) 29.3	(2) 29.6
Loin eye area, sq. in.	(6) 3.81	(4) 3.87	(1) 3.91	(5) 3.98	(7) 3.98	(3) 4.04	(2) 4.26
Lean cuts, %[d]	(4) 45.17	(5) 46.36	(1) 46.71	(7) 46.92	(6) 47.00	(3) 47.23	(2) 48.31
Fat iodine no.[e]	(4) 59.7	(2) 60.3	(5) 61.2	(3) 62.0	(1) 62.3	(7) 63.3	(6) 64.1

[a] Any lot means not underlined by the same line are significantly different at the 5% level.
[b] Lot numbers: (1) corn, (2) barley, (3) ½ corn ½ barley, (4) milo, (5) ½ corn ½ milo, (6) ½ corn ½ oats, (7) ¾ corn ¼ oats.
[c] Average of 3 measurements taken opposite 1st rib, last rib and last lumbar vertebra.
[d] Lean cuts expressed as % of chilled carcass with head on, leaf fat in.
[e] Fat sample for Iodine Number analysis taken opposite last lumbar vertebra.

The average percentage of the four lean cuts of the carcasses from the hogs fed milo was significantly lower than those from lots 2 (barley), 3 (½ corn ½ barley), 6 (½ corn ½ oats), and 7 (¾ corn ¼ oats).

Results of the Iodine Number determination of the backfat indicate that the hogs fed milo produced fat with a significantly lower Iodine Number than those fed corn, ½ corn ½ barley, ½ corn ½ oats, or ¾ corn ¼ oats. Results of this experiment tend to indicate that the Iodine Number of fat from pigs fed the following grains may be ranked from low to high as follows: milo, barley, corn and oats.

Sex differences occurred in many carcass characteristics. Gilt carcasses were found to have a higher carcass or ham specific gravity and greater *Longissimus dorsi* area at the 10th rib. Carcasses from gilts also were significantly longer, had a thinner backfat and yielded a higher percentage of lean cuts than those from barrows. This has been substantiated by many other reports.

Summary

Three feeding trials were conducted to test the effect of several finishing rations upon the rate and efficiency of gain and carcass characteristics of swine. One hundred and forty-seven pigs were individually self-fed in concrete-floor pens from an average weight of 69 lb. to an individual weight of approximately 200 lb. Individual feed lot and carcass data were obtained on all hogs.

The following results were noted:

1. Hogs fed corn (grain portion) made significantly faster gains than those fed barley, milo and ½ corn ½ oats; whereas, hogs fed barley made significantly slower gains than those fed corn, ½ corn ½ barley, ½ corn ½ milo, and ¾ corn ¼ oats.

2. Hogs fed corn (grain portion) required significantly less feed per pound of gain than those fed barley, ½ corn ½ milo, or ½ corn ½ oats, while those hogs fed barley required significantly more feed per pound of gain than all treatments except those fed ½ corn ½ oats.

3. Apparently oats could not replace ½ of the corn in a swine finishing ration without seriously lowering average daily gains and increasing feed required per pound of gain. However, oats replaced ¼ of the corn without seriously affecting average daily gains or feed per pound of gain.

4. Hogs fed barley tended to produce leaner carcasses with a lower dressing percent, less backfat, and a higher percentage of lean cuts, whereas those fed milo tended to produce carcasses with a lower yield of lean cuts.

5. Iodine Number of fat from hogs fed the following grains in this study tended to be ranked from low to high as follows: milo, barley, corn and oats.

Literature Cited

Brown, C. J., J. C. Hillier and J. A. Whatley. 1951. Specific gravity as a measure of the fat content of the pork carcass. J. Animal Sci. 10:97.

Crampton, E. W., G. W. Muir and R. G. Knox. 1940. Feeding value of Can. Western barley for bacon hogs. Sci. Agr. 20:365.

Duncan, David B. 1955. Multiple Range and Multiple F Tests. Biometrics 11:1.

Fletcher, J. L. 1953. Milo as feed for fattening pigs. Miss. Exp. Sta. Bul. 504.

Hochstetler, L. N., J. A. Hoefer, A. M. Pearson and R. W. Luecke. 1959. Effect of varying levels of fiber of different sources upon growth and carcass characteristics of swine. J. Animal Sci. 18:1397.

Jensen, A. H., D. E. Becker and S. W. Terrill. 1959. Oats as a replacement for corn in complete mixed rations for growing-finishing swine. J. Animal Sci. 18:701.

Kline, E. A. and L. N. Hazel. 1955. Loin area at tenth and last rib as related to leanness of pork carcass. J. Animal Sci. 14:659.

Loeffel, W. J. 1957. Grain sorghums as feeds for beef cattle and hogs. Nebr. Agr. Exp. Sta. Bul. 439.

Pearson, A. M., L. J. Bratzler, R. J. Deans, J. F. Price, J. A. Hoefer, E. P. Reineke and R. W. Luecke. 1956. The use of specific gravity of certain untrimmed pork cuts as a measure of carcass value. J. Animal Sci. 15:86.

Peo, E. R., Jr. and D. B. Hudman. 1958. Grain sorghum for growing-finishing swine. J. Animal Sci. 17:813.

Reciprocal Meat Conference. 1952. Pork Carcass Committee. pp. 118–125.

Wilson, J. W. and T. Wright. 1931. Barley as a fattening feed for cattle and swine for South Dakota. S. D. Exp. Sta. Bul. 262.

Zobrisky, S. E. 1959. Significant relationships in pork carcass evaluation. I. Lean cuts as a criteria for live hog value. J. Animal Sci. 18:420.

RELATIONSHIP BETWEEN CARCASS MEASUREMENTS AND ORGANOLEPTIC QUALITY IN COMMERCIAL AND COUNTRY-STYLE CURED HAM [1]

M. C. Heck and C. J. Brown
University of Arkansas, Fayetteville

CARCASS measurements currently stressed in breeding meat type hogs are backfat thickness, carcass length and loin eye area. Organoleptic qualities that affect the desirability of cuts from processed hams are aroma, flavor of fat and lean, texture, tenderness and juiciness. A knowledge of the relationships among carcass traits and organoleptic quality factors is lacking.

The purpose of this study was to determine whether relationships exist among certain carcass measurements and organoleptic quality in commercial and country-style cured hams.

Materials and Methods

Forty-eight hams from 24 U.S. No. 1 barrows and gilts, averaging 205 lb. at time of slaughter, were used in this study. The hogs were slaughtered packer style and chilled for 48 hours at 34° F. after which weights and carcass measurements were taken. Dressing percent was calculated from live shrunk weight and chilled carcass weights. Backfat thickness was the average of measurements on each side of the carcass at the first rib, last rib and last lumbar vertebra. Carcass length was the average length from the forward portion of the first rib to the lower portion of the aitch bone on the hanging carcass. Loin eye area was measured at the 10th rib.

The hams were cut from the sides and trimmed smoothly. The fat and skin were leveled back even with the aitch bone on all hams. The hams were coded and weighed. Yield of ham was calculated by dividing weight of the trimmed ham by the weight of the side. One ham from each side was randomly selected for commercial curing with a basic pickle formula [2] having a 70° Salometer reading at 60° F. These hams were stitch pumped at 40 lb. pressure until 10% of the pickle, by weight, had been injected into each ham. The hams were than covered with the amount of cure ("Quick Action" for dry cure mixture) that would adhere to the surface and placed on a shelf to cure for 21 days. The remaining ham was dry cured with a mixture which consisted of 8 lb. salt, 2 lb. medium brown sugar and 2 oz. potassium nitrate. These hams received one-half of the mixture at the first application and the remainder 5 days later. The amount of cure used per pound of ham was 1¼ oz. The dry cured hams were cured on a shelf for a period of 30 days. This dry cure recipe and method of use was recommended by Warner (1938) and was reported by Dunker and Hankins (1951) to have been used by 17% of all the farmers responding to a survey of meat curing methods using the dry cure with no previous pumping.

After 21 days in the case of commercial-style cure and 30 days in the case of country-style cure the hams were washed and brushed to remove the surface salt. After brushing, the hams were soaked for 1 hour in warm water (120° F.). They were hung shank-end down in stockinette in an electrically heated smokehouse until dry and smoked for 24 hours. The maximum smokehouse temperature was 120° F. The commercial cured hams were smoked before the longer cured country style hams and following smoking these hams were stored in a refrigerated room of 40° F. The dry cured hams remained at room temperature after smoking and were stored for 14 days where the temperature ranged from 82–87° F. All of the hams were weighed after curing, after smoking and after 14 days of storage. The amount of shrink, during these operations, was calculated and recorded as processing shrink.

A trained taste panel gave a 2 cm. thick center slice of each ham an organoleptic score. Scoring started soon after the dry cured hams had been stored 14 days and before the onset of mold growth. Miller and Ziegler (1936) reported that the salt in hams, cured by various methods, did not become well distributed throughout the meat until approximately 60 days after the beginning of the various cures. In this study the amount of salt

[1] Published with the approval of the Director of the Arkansas Agricultural Experiment Station.
[2] The "Quick Action" cure of B. Heller and Co.

in each sample was not calculated and the curing and storage period was less than 60 days for the country-style cured hams. To correct for salt equalization a 2 cm. thick portion of the outer surface of each center slice was removed before wrapping in aluminum foil for cooking. The samples were cooked at 170° C. in an electric rotary hearth test baking oven. They were removed from paired hams for each test and were cooked for the same length of time to an internal temperature of 75° C. The warm liquid was drained from the samples and they were scored immediately. Scores were tabulated for six organoleptic traits, as outlined by Lowe (1949), using a scale ranging from 10 to 0, where 10 was extremely good and 0 was unacceptable. Paired samples from four hogs were scored at each sitting. The organoleptic quality factors scored were aroma, flavor of fat, flavor of lean, texture, tenderness and juiciness. The average scores of five judges for each of the samples were used for analysis.

Results and Discussion

Means and standard deviations of carcass, ham and organoleptic measurements are presented in table 1. These values indicate that these were typical carcasses from U.S. No. 1 live hogs. The ranges in carcass weight, length and backfat thickness were 130 to 180 lb., 28.0 to 31.3 in. and 1.2 to 2.1 in., respectively. The fresh hams ranged in weight from 11.4 to 17.6 lb. The paired hams for country-style and commercial curing had an average initial weight of 14.3 and 14.4 lb., respectively. Commercial cured hams shrank 3.6% less and were 0.6 lb. heavier after processing. The curing brine, which was pumped into the commercially cured hams, apparently reduced the shrinkage.

TABLE 1. MEANS AND STANDARD DEVIATIONS OF TRAITS

Trait	Mean		Standard deviation	
Carcass measurement				
Chilled weight, lb.	153.1		14.8	
Dressing percent, %	74.6		1.9	
Backfat thickness, in.	1.5		0.3	
Carcass length, in.	29.5		1.0	
Loin area, sq. in.	3.7		0.4	
Cure[a]	C_1	C_2	C_1	C_2
Ham measurement				
Initial weight, lb.	14.3	14.4	1.6	1.6
Yield of ham, %	18.9	18.9	2.9	3.0
Processing, shrink %	12.3	8.7	4.3	3.2
Cured weight, lb.	12.5	13.1	1.2	1.3
Organoleptic measurement				
Aroma	7.3	7.2	0.6	0.6
Fat flavor	6.9	7.0	0.7	0.7
Lean flavor	7.1	7.2	1.0	0.8
Texture	7.2	6.9	0.6	0.7
Tenderness	7.4	6.9	0.6	0.8
Juiciness	7.2	7.2	0.5	0.7

[a] C_1, Country-style cured hams; C_2, Commercial cured hams.

Correlations presented in table 2 were high enough to suggest that carcass weight, backfat thickness, ham yield and processing shrink may be indicative of eating quality. The correlations of carcass length and loin area with organoleptic quality factors were small and not significant. The correlations between cured weight of the ham and taste panel scores were small. These relationships indicated a tendency for those carcass traits indicative of fatness to be more closely related to eating quality.

Prior to cutting the carcass, average backfat thickness was the best indicator of eating quality and about equal in predictability to yield of ham after the carcass was cut. The correlation between backfat thickness and the average of all taste panel scores was 0.71 and 0.75 respectively, for country and commercial style cures. A similar comparison of correlations between yield of ham and the average of all taste panel scores was 0.76 and 0.75 for these respective cures.

Shrinkage during processing was more closely associated with eating quality than of any of the characteristics studied. The correlation between shrinkage and the average of all organoleptic factors scored by the panel was 0.90 for country style and 0.72 for commercial style curing. Drippage losses, evaporation and concentration of the curing ingredients in the meat were factors that might be expected to influence organoleptic scores during processing.

Differences in the magnitude of correlations between carcass measurements and taste panel scores, in table 2, when hams were cured country style and when they were commercially cured were not significant. There appeared to be a consistently closer relationship between chilled weight, dressing percent, and backfat thickness and the taste panel scores of aroma, flavor of fat, flavor of lean and juiciness among the country-style cured hams. Carcass weight, dressing percent and backfat thickness are all functions of the degree of fatness. Perhaps, this indicates that fat influenced these taste panel scores more when hams were cured country-style. Initial weight and yield of ham were consistently more closely associated with aroma, texture and tenderness when the hams were commercially cured. Perhaps the added water in the tissue, from stitch

TABLE 2. CORRELATIONS[a] BETWEEN CARCASS MEASUREMENTS AND FACTORS OF ORGANOLEPTIC QUALITY OF HAMS CURED BY TWO METHODS

Item	Cure[b]	Aroma	Flavor of fat	Flavor of lean	Texture	Tenderness	Juiciness	Average[c]
Chilled weight	C_1	.56	.53	.61	.40	.15	.57	.60
	C_2	.48	.38	.48	.50	.45	.41	.55
Dressing percent	C_1	.39	.44	.40	.32	.21	.55	.48
	C_2	.13	.14	.16	.27	.32	.12	.25
Backfat thickness	C_1	.60	.62	.73	.56	.28	.65	.71
	C_2	.60	.49	.64	.63	.67	.64	.75
Carcass length	C_1	.38	.23	.32	.24	.09	.32	.33
	C_2	.43	.36	.38	.33	.22	.23	.38
Loin area	C_1	−.21	−.08	.10	.07	.19	−.07	.03
	C_2	.11	.12	.27	−.02	.06	.12	.13
Initial ham wt.	C_1	.25	.49	.63	.34	.05	.46	.50
	C_2	.46	.26	.55	.55	.49	.53	.60
Yield of ham	C_1	.54	.72	.87	.51	.14	.70	.76
	C_2	.59	.38	.69	.69	.63	.61	.75
Processing shrink	C_1	.75	.79	.88	.70	.34	.84	.90
	C_2	.59	.49	.65	.57	.65	.58	.72
Cured ham wt.	C_1	.08	.17	.28	.06	.09	.13	.14
	C_2	.33	.11	.42	.44	.35	.40	.44

[a] Twenty-two degrees of freedom; "r" value of .52 and .40 required for significance at $P<.01$ and $P<.05$, respectively.
[b] C_1, Country-style cure; C_2 Commercial cure.
[c] Average of all items scored by taste panel.

pump curing influenced these taste panel scores more when hams were commercially cured. Since chemical analysis of the hams were not made, it was not possible to substantiate these trends.

In table 3 are presented the standard partial regression coefficients in which chilled weight, carcass yield, backfat thickness, carcass length and loin area were considered as independent variables and each of the factors of organoleptic quality were considered as a dependent variable in a separate multiple regression analysis for each cure. Multiple correlations with carcass measurements were highly significant for flavor of lean and juiciness by both curing methods and for aroma of the country cured hams. Multiple correlations with carcass measurements were significant for aroma, texture and tenderness of commercially cured hams and for flavor of fat of country-style cured hams. These five measurements accounted for between 25% of the variance in the case of tenderness of country-style cured hams and 59% of the variance in the case of flavor of

TABLE 3. STANDARD PARTIAL REGRESSION COEFFICIENTS AND MULTIPLE CORRELATIONS OF TASTE PANEL SCORES ON CERTAIN CARCASS MEASUREMENTS

Item	Cure[a]	Aroma	Flavor of fat	Flavor of lean	Texture	Tenderness	Juiciness
Chilled weight	C_1	.84	1.11	.97	−.55	−1.60	−.06
	C_2	.15	−.44	−.03	.47	−.21	.60
Dressing percent	C_1	−.16	−.16	−.28	.29	.71	.37
	C_2	−.35	−.03	−.26	−.22	.11	−.47
Backfat thickness	C_1	.17	.15	.36	.72	.81	.51
	C_2	.56	.63	.70*	.44	.76*	.55
Carcass length	C_1	−.18	−.59	−.49	.25	.67	.06
	C_2	.23	.45	.17	−.09	.02	−.29
Loin area	C_1	−.40	−.22	−.01	.09	.32	−.16
	C_2	.05	.11	.27	−.10	.08	.11
R	C_1	.72**	.68**	.77**	.58	.50	.73**
	C_2	.69*	.56	.73**	.65*	.68*	.70**

[a] C_1, Country-style cured hams; C_2 Commercial cured hams.
* $P<.05$.
** $P<.01$.

lean of country-style cured hams. Carcass measurements accounted for the highest percentage of variance in the scores of flavor of lean with both curing procedures.

The standard partial regression coefficients in table 3 are quite variable but in general indicate the trends that were apparent in table 2. Chilled weight was a distinctly more important source of variation in all taste panel scores except juiciness when hams were cured country-style. Except for tenderness of country-style cured hams, standard partial regression coefficients of taste panel scores on dressing percent were low and mostly negative. Only for backfat thickness were all standard partial regression coefficients positive for all scores on both cures. Somewhat higher standard partial regression coefficients of score of juiciness, aroma, flavor of fat and lean on backfat were noted when hams were commercially cured. Only in the case of tenderness score was the standard partial regression coefficient distinctly larger for all carcass measurements in favor of country-style cured hams.

It is recognized that visual appraisal of live hogs for carcass traits may be misleading and that differences in proportions and quality of carcass and cuts can be more accurately estimated from the carcass than from the live hog (Bratzler and Margerum, 1953; Hetzer *et al.*, 1956). Relationships among various physical and chemical carcass measurements and carcass quality have been indicated (Hetzer *et al.*, 1950; Kline and Hazel, 1955; Self *et al.*, 1957; Pearson *et al.*, 1958a, b; Zobrisky *et al.*, 1959a, b, c; and Briskey *et al.*, 1960). Certain physical, chemical and organoleptic relationships in fresh pork have been investigated by Judge *et al.* (1960). The authors are not aware of studies of the relationship between carcass measurements and eating quality of cured hams. The data presented suggest that among lots of hogs within a grade, carcass measurements may be of value as indicators of eating quality. Chilled carcass weight and backfat thickness appeared the best indicators of eating quality among the carcass measurements investigated.

Summary

Cured ham slices from 24 U.S. No. 1 slaughter hogs were used to study relationships between carcass measurements (chilled carcass weight, dressing percent, backfat thickness, carcass length, loin area, ham yield and processing shrink) and taste panel scores (aroma, flavor of fat, flavor of lean, texture, tenderness and juiciness). Multiple correlations between carcass measurements and the various taste panel scores ranged between 0.50 and 0.77 indicating the possible use of carcass measurements as indicators of eating quality in pork. Chilled carcass weight, backfat thickness and processing shrink appeared the best indicators of eating quality among carcass measurements studied.

Literature Cited

Bratzler, L. J. and E. P. Margerum, Jr. 1953. The relationship between live hog scores and carcass measurements. J. Animal Sci. 12:856.

Briskey, E. J., W. G. Hoekstra, R. W. Bray and R. H. Grummer. 1960. A comparison of certain physical and chemical characteristics of eight pork muscles. J. Animal Sci. 19:214.

Dunker, C. F. and O. G. Hankins. 1951. A survey of farm meat-curing methods. U.S.D.A. Cir. 894.

Hetzer, H. O., O. G. Hankins, J. X. King and J. H. Zeller. 1950. Relationship between certain body measurements and carcass characteristics in swine. J. Animal Sci. 9:37.

Hetzer, H. O., J. H. Zeller and O. G. Hankins. 1956. Carcass yields as related to live hog probes at various weights and locations. J. Animal Sci. 15:257.

Judge, M. D., V. R. Cahill, L. E. Kinkle and F. E. Deatherige. 1960. Pork quality. II. Physical, chemical and organoleptic relationships in fresh pork. J. Animal Sci. 19:145.

Kline, E. A. and L. N. Hazel. 1955. Loin area at tenth and last rib as related to leanness of pork carcasses. J. Animal Sci. 14:659.

Lowe, Belle. 1949. Organoleptic tests developed for measuring the palatability of meat. Proc. 2nd An. Rec. Meat Conf., National Livestock and Meat Board.

Miller, R. C. and P. T. Ziegler. 1936. The progress of the distribution of salt in ham during the curing process. J. Agr. Res. 52:225.

Pearson, A. M., L. J. Bratzler and W. T. Magee. 1958a. Some simple cut indices for predicting carcass traits of swine. I. Cut-out and loin lean area. J. Animal Sci. 17:20.

Pearson, A. M., L. J. Bratzler and W. T. Magee. 1958b. Some simple cut indices for predicting carcass traits of swine. II. Supplementary measures of leanness. J. Animal Sci. 17:27.

Self, H. L., R. W. Bray and R. J. Reierson. 1957. Lean cut yield and an evaluation of hams and loins of U.S.D.A. pork carcass grades. J. Animal Sci. 16:642.

Warner, K. F. 1938. Pork on the farm. Killing, curing and canning. U.S.D.A. Bul. 1186.

Zobrisky, S. E., D. E. Brady, J. F. Lasley and L. A. Weaver. 1959a. Significant relationships in pork carcass evaluation. I. Lean cuts as criteria for live hog value. J. Animal Sci. 18:420.

Zobrisky, S. E., D. E. Brady, J. F. Lasley and L. A. Weaver. 1959b. Significant relationships in pork carcass evaluation. II. Measurements and cuts of fat as criteria for live hog value. J. Animal Sci. 18:583.

Zobrisky, S. E., D. E. Brady, J. F. Lasley and L. A. Weaver. 1959c. Significant relationships in pork carcass evaluation. III. Dressing percent as a criterion for live hog value. J. Animal Sci. 18:589.

HERITABILITY OF GROWTH RATE IN INBRED SWINE BASED ON A CROSSBRED FOUNDATION [1]

H. F. EL-ISSAWI [2] AND W. E. REMPEL

University of Minnesota, St. Paul [3]

ESTIMATES of heritability of growth rate have been reported by several workers for different breeds of swine. The estimates reported in the literature have been reviewed by Fredeen (1953, 1958) and Craft (1958). The actual estimates vary in magnitude from 0.14 to 0.66. The individual estimates are frequently based on small bodies of data and therefore subject to large sampling error. This is true of earlier estimates computed from the Minnesota data (Comstock *et al.*, 1942; Nordskog *et al.*, 1944).

Growth data have been accumulated at Minnesota on three breeds of swine developed at four experiment stations from 1938 to 1958. This manuscript reports estimates of the heritability of growth rate based on all those data. A particular purpose was to discover whether heritability is higher in the Minnesota No. 3 than in the Minnesota No. 1 and No. 2. This was a matter of special interest because the No. 3 was initiated from a foundation stock formed by interbreeding animals from numerous breed sources in a deliberate attempt to increase the genetic variance and thereby enhance the opportunity for effective selection. In addition the Minnesota No. 1 has been maintained as a relatively small closed herd since 1938.

Materials and Methods

The growth rate data came from Minnesota No. 1 pigs at Rosemount and Grand Rapids; Minnesota No. 2 pigs at Crookston, Rosemount and Morris; and Minnesota No. 3 pigs at Rosemount and Morris. All of these breeds were started from crossbred foundations (Brugman *et al.*, 1949; Roubicek *et al.*, 1951; Sumption, 1957). Growth rate was measured as average daily gain from weaning at 56 days of age to 140 days of age in the Minnesota No. 3's, the No. 2's at Morris and a portion of the No. 2's at Rosemount. For all other pigs it was measured as average daily gain from 56 days to 154 days of age.

Estimates of heritability were obtained by doubling the regression of offspring on dam. The intra-sire regression was used where pedigree information permitted. Intra-sire regressions could not be computed from data on those animals which had been produced from multiple-sire mating.

The data were subdivided into sets. In each set all data were from the same station and breed and were on dams farrowed in the same year and season and on offspring farrowed in the same year and season. The Minnesota No. 2 data from Rosemount were from two lines tracing to different foundation ancestry and were subdivided accordingly. Each set of data was analyzed separately. Variables were growth rate of dam (x) and average growth rate of the offspring (y) of each dam. No sex correction was made in the offspring data, that is, sex was left as a source of random variance. Each pair of x and y values was given equal weight even though the number of offspring varied from one dam to another. However, offspring per dam were almost always seven or more and rarely exceeded eleven. With this range, little extra information would have been added by optimum weighting.

The analyses of variance and covariance were as follows:

Source of variation	d.f.	Sx^2	Sxy	Sy^2
Sires	s–1			
Dams within sires	d–s	A_1	B_1	C_1
Total	d–1	A_2	B_2	C_2

where: s = number of sires and d = total number of dams.

Intra-sire regression estimates were computed as B_1/A_1 and gross regression estimates as B_2/A_2. The standard error of a regression coefficient was estimated as $\sqrt{\frac{C-B^2/A}{fA}}$ where f symbolizes degrees of freedom, (d-s-1) in the

[1] Paper No. 4547, Scientific Journal Series of the Minnesota Agricultural Experiment Station with cooperation of AHRD, ARS, The Regional Swine Breeding Laboratory, U.S.D.A.

[2] Present address, Cairo, Egypt.

[3] The authors gratefully acknowledge the help of R. E. Comstock in this study.

case of intra-sire regression or (d-2) in the case of gross regression.

The analyses from sets of data were also pooled in various ways to compress the total information into fewer estimates. The procedure was by summation (separately) of degrees of freedom, sum of squares in x, sum of squares in y and the sum of products for "dams within sires" and "total" as indicated below:

Source of variation	d.f.	Sx^2	Sxy	Sy^2
Dams within sires and sets	$\Sigma(d-s)$	ΣA_1	ΣB_1	ΣC_1
Total within sets	$\Sigma(d-1)$	ΣA_2	ΣB_2	ΣC_2

Regression coefficients and their standard errors were then computed in analogous fashion to procedures followed for individual sets of data. For example, the intra-sire regression estimate was obtained as $\Sigma B_1/\Sigma A_1$ and the associated standard error as:

$$\sqrt{\frac{\Sigma C_1-(\Sigma B_1)^2/\Sigma A_1}{[\Sigma(d\text{-}s)-1]\,\Sigma A_1}}$$

Analyses were first pooled to give a single analysis for each breed at each station at which data on the breed had been obtained. Further pooling was then done to give a single analysis for each breed. Finally all analyses were pooled to give just one analysis for all data in which the total degrees of freedom within sets was 1419.

Results and Discussion

The heritability estimates obtained by both intra-sire and total regression of offspring on dam show considerable fluctuation from year to year in both magnitude and sign. The standard errors of the individual estimates are large, as would be expected from the small number of degrees of freedom. Pooled estimates for each breed are shown in table 1. They represent more reliable estimates of heritability than the yearly estimates for each breed under the conditions prevailing during the time these data were collected.

Breed differences in the heritability estimates fall short of statistical significance in all instances. The one estimate (−.28) that is sharply different from the others was based on a very restricted amount of data and should be discounted accordingly. In the absence of any substantial evidence for breed differences it was considered desirable to pool the breed estimates. As seen in table 1 they are 0.14 ± 0.08 for the intra-sire estimate and 0.28 ± 0.06 for the gross regression method.

An advantage of the parent-offspring regression as the basis for estimating heritability is that it is subject to less bias from variance in genotype-environment interaction than the half-sib correlation method. This is because parents and offspring develop in different environments in so far as year effects are concerned.

In the present study the data were employed in such a way that total variance was measured among contemporary individuals in the same herd and location. When that is the case the gross regression method, like the intra-sire regression method, yields an unbiased estimate of one-half of the heritability so long as mating is random among selected males and females. Random assignment of females to sires (except for avoiding full-sib matings) has been the consistent practice in the Minnesota swine breeding project. Hence, there is believed to be no reason for bias in the gross regression estimate of heritability. That being the case, and since it has the smallest standard error, this estimate (0.28 ± 0.06) is considered by the authors as the best estimate of the heritability of growth rate by dam-offspring regression from the accumulated Minnesota data.

Since females were assigned to sires at

TABLE 1. REGRESSION ANALYSES AND HERITABILITY ESTIMATES FOR DAILY GAIN

Breed	Method[a]	d.f.	Sy^2	Sxy	Sx^2	b	s_b	h^2
Minn. No. 1	A	218	3.4369	0.3122	3.9473	0.08	0.06	0.16
	B	472	8.9144	1.3480	9.4011	0.14	0.04	0.28
Minn. No. 2	A	198	3.5039	0.3813	3.8486	0.10	0.07	0.20
	B	571	13.4767	1.5177	11.1082	0.14	0.05	0.28
Minn. No. 3	A	35	0.7272	−.0819	0.6042	−.14	0.19	−.28
	B	376	6.0967	0.9383	7.5453	0.12	0.05	0.24
All breeds	A	451	7.6680	0.6116	8.4001	0.07	0.04	0.14
	B	1419	28.4878	3.8040	28.0546	0.14	0.03	0.28

[a] A=Dams within sires and sets. B=Total within sets.

random (except that full-sib matings were avoided) the gross regression method within sets yields an unbiased estimate of one-half of the heritability as does the intra-sire regression. The estimate based on gross regressions in this study are considered by the authors as the more reliable because of the greater numbers of degrees of freedom on which they are based.

Estimates of heritability of daily gain reported in the literature vary from 0.14 to 0.66. This wide range of values may represent genuine differences among populations studied, but is more likely due to imprecision of the various estimates. In the present study, estimates obtained from the smaller bodies of data generally had relatively large standard errors. In the case of the Minnesota No. 3, for example, the estimate at Morris based on 81 degrees of freedom had a standard error of 0.10. At Rosemount, where 295 degrees of freedom were available, the standard error of the estimate was only 0.05. Many estimates of heritability have large sampling errors because they are based on limited amounts of data.

There is also a chance for bias in heritability estimates obtained from variance component estimates because part of the half-sib correlation may be environmental and because of possible genotype-environment interactions. This applies to the estimates reported by Fredeen and Jonsson (1957). Their estimates of 0.66 for males and 0.35 for females were based on data from Danish pig testing stations where hand feeding is practiced. Their sire component of variance included any component arising from genetic or environmental differences between herds. Their results are therefore not quite comparable to the ones reported here. The estimates obtained in this study are in reasonable agreement with those reported in the literature, except the ones reported by Fredeen and Jonsson.

Differences in genetic and environmental variances of populations are potential sources of variation among estimates of heritability. The data therefore fail to provide a basis for concluding that breed differences existed in the heritability of growth rate. This is a matter of special interest because the Minnesota No. 3 is a recent derivative from a broad genetic base, and the Minnesota No. 1 had a considerably higher average inbreeding coefficient for the period in which data were collected, and in many respects appears more uniform in phenotype.

Cases where different methods of analyses for the same data yield different estimates of heritability (Whatley, 1942; Hazel *et al.*, 1943; Baker *et al.*, 1943; Krider *et al.*, 1946) can also be explained most reasonably by sampling error.

Summary

Estimates of heritability of daily gain from weaning to 140 or 154 days of age were obtained for pigs of the Minnesota No. 1, Minnesota No. 2 and Minnesota No. 3 breeds on an intra-station and intra-year basis. Estimates were computed on the basis of the intra-sire regression of offspring on dam and from gross regression of offspring on dam. Pooled estimates were obtained by both methods for each breed separately. The breed estimates did not differ significantly from each other so that they too could be pooled. The final pooled estimates were 0.14 ± 0.10 based on intra-sire regression, and 0.28 ± 0.06 based on gross regression. The degrees of freedom for the two estimates were 451 and 1419 respectively. The method of gross regression is suggested as a preferable method for some kinds of data. The estimate by that method is considered the better on these data. Of special interest is the fact that heritability was found to be no higher in the Minnesota No. 3 (a recent derivative from a broad genetic base) than in the other two breeds.

Literature Cited

Baker, M. L., L. N. Hazel and C. F. Reinmiller. 1943. The relative importance of heredity and environment in the growth of pigs at different ages. J. Animal Sci. 2:2.

Brugman, H. H., L. M. Winters and D. L. Dailey. 1949. A genealogy study of the Minnesota No. 1 hog. Minn. Agr. Exp. Sta. Tech. Bul. 184.

Comstock, R. E., L. M. Winters, P. S. Jordan and O. M. Kiser. 1942. Measures of growth rate for use in swine selection. J. Agr. Res. 65:379.

Craft, W. A. 1958. Fifty years of progress in swine breeding. J. Animal Sci. 17:960.

Fredeen, H. T. 1953. Genetic aspects of Canadian bacon production. Publ. Depart. Agr. Canada. No. 889.

Fredeen, H. T. 1958. The genetic improvement of swine. Commonwealth Bureau of Animal Breeding and Genetics. Reprint No. 38.

Fredeen, H. T. and P. Jonsson. 1957. Genetic variance and covariance in Danish Landrace swine as evaluated under a system of individual feeding of progeny test groups. Z. Tierz. Zucht. Biol. 70:348.

Hazel, L. N., M. L. Baker and C. F. Reinmiller. 1943. Genetic and environmental correlations between the growth rate of pigs at different ages. J. Animal Sci. 2:118.

Krider, J. L., B. W. Fairbanks, W. E. Carroll and E. Roberts. 1946. Effectiveness of selection for rapid and for slow growth in Hampshire swine. J. Animal Sci. 5:3.

Nordskog, A. W., R. E. Comstock and L. M. Winters. 1944. Hereditary and environmental factors affecting growth rate in swine. J. Animal Sci. 3:257.

Roubicek, Carl B., L. M. Winters and O. M. Kiser. 1951. A genealogical study of the Minnesota No. 2 hog. Minn. Agr. Exp. Sta. Tech. Bul. 193.

Sumption, L. J. 1957. An analysis of the early development of the Minnesota No. 3 inbred line of swine. Ph.D. Thesis. University of Minnesota, St. Paul.

Whatley, J. A. 1942. Influence of heredity and other factors affecting growth rate in swine. J. Animal Sci. 3:257.

INFLUENCE OF PROTEIN SOURCE ON TOXICITY OF GOSSYPOL IN SWINE RATIONS [1]

E. T. KORNEGAY,[2] A. J. CLAWSON, F. H. SMITH AND E. R. BARRICK [3]

North Carolina Agricultural Experiment Station, Raleigh

EFFORTS to define the level of free gossypol which can be fed to swine without causing toxicity have met with limited success. A number of investigations have shown that cottonseed meals with similar levels of free gossypol may show marked differences in growth and toxicity. This indicates that factors other than free gossypol *per se* are involved. A limited amount of evidence is now being accumulated which shows that the level of protein (Cabell and Earle, 1956; Hale and Lyman, 1957; Stevenson and Earle, 1957; Smith *et al.*, 1958) and quality of protein (Eagle *et al.*, 1956; Cabell and Earle, 1956; Cabell, 1957; Smith, 1957; Clawson and Barrick, 1957) in the ration may have an influence on the toxicity of gossypol.

The purpose of this study was to investigate the influence of protein source on the performance and gossypol tolerance of pigs fed rations containing graded levels of free gossypol. Because all commercial cottonseed meals contain some gossypol, it was considered desirable to investigate rations in which there was no gossypol. Meals containing low and high quality protein, with added free gossypol, were compared as sources of supplemental protein for swine.

Experimental

This study consisted of two experiments in which 72 individually fed weanling pigs were used. In each experiment, pigs were supplied water and feed *ad libitum*. Feed wastage was accumulated daily and recorded. Individual feed consumption was recorded and weight was measured at triweekly intervals for Experiment I and biweekly intervals for Experiment II. The duration of the experiments were 15 and 16 weeks in Experiments 1 and 2 respectively. The experiments were conducted during two consecutive seasons: fall of 1958 and spring of 1959.

In each experiment, 36 weanling pigs were allotted on the basis of breed and litter to six replications. Pigs in a litter were randomly assigned to the six treatments in each replication. Replications and litters were confounded. Six pigs from each of two litters were used to complete two replications in each experiment. The other replications contained 4 or 5 pigs from one litter and enough pigs from another litter of the same breed to complete the replication.

In both experiments, graded levels of free gossypol, 0.00, 0.02 and 0.04%, were added to rations containing two sources of supplemental protein. Peanut meal and soybean meal were used as the sources of protein in Experiment I and cottonseed meal and soybean meal were used in Experiment II. The composition of the rations used is presented in tables 1 and 2. Cottonseed meats from one source, which had previously been screened to remove most of the hulls and stored at 0° F., were used as the source of free gossypol in both experiments. An analysis of the meats prior to Experiment I showed them to contain 0.80% free gossypol. When they were rechecked prior to initiating Experiment II, a value of 0.98% free gossypol was obtained. There may have been a discrepancy in sampling the cottonseed meats for gossypol analysis which would have resulted in higher levels of free gossypol being used in Experiment I than in Experiment II. Because of the free gossypol already present in the cottonseed meal, a zero level was not possible in the control cottonseed meal ration—the actual level fed was 0.0064% free gossypol.

Crude protein levels of approximately 14½% were used in Experiment I until each pig had consumed 150 lb. of feed. The crude protein level was then reduced 2%. A 14%

[1] Approved for publication as Paper No. 1271 in the Journal Series of North Carolina Agricultural Experiment Station.

[2] This material is based upon part of a thesis submitted by the senior author in partial fulfillment of the requirements for the M.S. degree at North Carolina State College. Present address: Department of Animal Husbandry, Michigan State University, East Lansing.

[3] The authors acknowledge the assistance of the National Cottonseed Products Association, Inc., Dallas, Texas for grants-in-aid and U. S. Department of Agriculture, Southern Regional Research Laboratories for special analysis of the meals.

TABLE 1. PERCENTAGE COMPOSITION OF RATIONS FED TO PIGS IN EXPERIMENT I

Source of protein	Peanut meal			Soybean meal		
Free gossypol level,%	0.00	0.02	0.04	0.00	0.02	0.04
Ingredient:						
Corn	80.8	79.7	78.6	79.8	78.7	77.6
Peanut meal (55%)	13.0	11.5	10.0	....	....	....
Soybean meal (45%)	....	....	....	14.0	12.5	11.0
Alfalfa meal (17%)	3.0	3.0	3.0	3.0	3.0	3.0
Limestone	0.7	0.7	0.7	0.7	0.7	0.7
Defluorinated phosphate	1.0	1.0	1.0	1.0	1.0	1.0
Trace mineral salt	0.5	0.5	0.5	0.5	0.5	0.5
Vitamin antibiotic mix[a]	1.0	1.0	1.0	1.0	1.0	1.0
Cottonseed meats[b]	....	2.6	5.2	....	2.6	5.2
Calculated analysis:						
Crude protein[c]	14.9	15.0	15.0	14.0	14.2	14.3
Calcium	0.7	0.7	0.7	0.7	0.7	0.7
Phosphorus	0.4	0.5	0.5	0.5	0.5	0.5

[a] One pound of the vitamin antibiotic pre-mix supplied Vit. A—100,000 U.S.P. units; Vit. D_2—100,000 U.S.P. units; Vit. E—100 I units; Riboflavin—300 mgs.; Calcium Pantothenate—800 mgs.; Niacin—2,000 mgs.; Choline—10,000 mgs.; Vit. B_{12}—1 mg.; Chlortetracycline Hydrochloride—1 gm.; Mn—1.2%; Zn—0.54%; I—0.024%; Fe—0.4%; Cu—0.04%; and Co—0.004%.
[b] Contained by analysis 0.80% free gossypol.
[c] Crude protein was reduced approximately 2% after each pig had consumed 150 pounds of feed.

crude protein level was used throughout Experiment II.

In both experiments, only enough feed was mixed at one time to last approximately 2 to 3 weeks. This was done in order to have fresh feed and to reduce the chances of loss or inactivation of the free gossypol. Heywang *et al.* (1952) noted that pure gossypol, when mixed with diets, is lost or inactivated after a short time. Kupperman and Karon (1955) have shown that temperature, length of storage, components of the diet, concentration of gossypol added, and final percentage of gossypol in the mixture are all factors which may contribute to loss or inactivation of free gossypol. An analysis for free gossypol in the mixed diets (Experiment II), after approximately 2 months in storage at room temperature, showed a decrease of about one-half in the original amount added. Total gossypol showed little change.

A digestion trial, using the chromium oxide indicator method (Schurch *et al.*, 1952) was conducted after pigs had been on Experiment II for 12 weeks. Sufficient quantities of each ration were prepared at one time by mixing one percent chromium oxide to the regular diets. The rations were sampled at the time

TABLE 2. PERCENTAGE COMPOSITION OF RATIONS FED TO PIGS IN EXPERIMENT II

Source of protein	Cottonseed meal			Soybean meal		
Free gossypol level,%	0.00	0.02	0.04	0.00	0.02	0.04
Ingredient:						
Corn	78.5	78.3	78.2	81.9	81.2	80.5
Cottonseed meal (41%)[a]	15.7	14.2	12.7	....	....	....
Soybean meal (50%)[b]	....	....	....	12.3	11.0	9.7
Alfalfa meal (17%)	3.0	3.0	3.0	3.0	3.0	3.0
Limestone	0.9	0.9	0.9	0.4	0.4	0.4
Defluorinated phosphate	0.8	0.8	0.8	1.3	1.3	1.3
Trace mineral salt	0.5	0.5	0.5	0.5	0.5	0.5
Vitamin antibiotic mix[c]	0.5	0.5	0.5	0.5	0.5	0.5
Zinc supplement	0.1	0.1	0.1	0.1	0.1	0.1
Cottonseed meats[d]	....	1.6	3.3	....	2.0	4.0
Calculated analysis:						
Protein	14.0	14.0	14.0	14.0	14.0	14.1
Calcium	0.7	0.7	0.7	0.7	0.7	0.7
Phosphorus	0.5	0.5	0.5	0.5	0.5	0.5

[a] Commercial Solvent Extracted Meal contained: 6.55% N; 0.041% free and 1.23% total gossypol, and 2.75% N of Epsilon amino lysine as analyzed by the Southern Regional Research Laboratory.
[b] Dehulled solvent extracted.
[c] Same as used in Experiment I.
[d] Contained by analysis 0.98% free gossypol and 1.296% total gossypol.

of mixing and the samples were stored at room temperature. Grab samples of the feces were taken for 3 consecutive days following a 4-day preliminary period during which only the rations containing chromium oxide were fed. Clawson *et al.* (1955) showed that this sampling procedure resulted in digestion coefficients comparable to the conventional method. The feces samples were oven dried at 60° C. and stored at room temperature. The chromium oxide analyses of feed and feces were made by a perchloric acid-digestion method (Smith, 1955). Proximate analysis (A.O.A.C., 1945) was made of feed and feces samples. The procedure for determining total gossypol was by the method of Smith (1958). Estimation of free gossypol was by the method of Smith (1946a, 1946b) with modifications by F. H. Smith (unpublished, 1956).

The average daily gain and average daily feed intake until the time of death were used in statistical analyses of the data.

Results and Discussion

The results of Experiment I, using peanut meal and soybean meal as the sources of supplemental protein with graded levels of free gossypol added to the rations, are shown in table 3. Pigs fed soybean meal rations had significantly greater ($P<0.01$) feed intake, daily gain and feed efficiency than did pigs fed peanut meal rations. The addition of free gossypol to the rations greatly decreased feed consumption and daily gain; whereas, feed efficiency was only slightly reduced. There were significant ($P<0.05$) protein-source x level of free gossypol interactions associated with feed consumption and daily gain after 15 weeks on experiment. After adjusting daily gains for feed intake by use of covariance analysis, soybean meal rations were still superior to peanut meal rations. The effect of levels of free gossypol, however, was not as great after gains were adjusted for feed intake.

All six pigs fed the soybean meal rations, with 0.04% added free gossypol, died from gossypol toxicity. Eight pigs fed peanut meal rations died from gossypol toxicity; two at the 0.02% level and all six at the 0.04% level.

The results of Experiment II using soybean meal and cottonseed meal as the sources of supplemental protein with graded levels of free gossypol added to the rations are shown in table 4. Pigs fed the soybean meal ration again had significantly ($P<0.01$) greater feed intake, daily gain and feed efficiency than did pigs fed the cottonseed meal rations. The addition of free gossypol decreased feed consumption and daily gain; however, the effect of free gossypol appeared to be less in Experiment II than in Experiment I. Feed efficiency was only slightly reduced by the addition of free gossypol to the rations. Again the effect of levels of free gossypol was not as great after adjustment of daily gain for feed intake.

TABLE 3. PERFORMANCE DATA OF PIGS FED GRADED LEVELS OF FREE GOSSYPOL WITH TWO SOURCES OF PROTEIN

(EXPERIMENT I)

Source of protein	Peanut meal			Soybean meal		
Free gossypol level,%	0.00	0.02	0.04	0.00	0.02	0.04
No. of pigs per treatment	6	6	6	6	6	6
Av. initial weight, lb.	35	34	33	32	32	33
Av. final weight, lb.[a]	156	130	69	202	182	93
Av. daily feed intake, lb.						
9 weeks	3.86	3.75	2.99	5.31	4.70	3.33
15 weeks	4.91	3.92	2.80	6.27	5.26	3.01
Av. daily gain, lb.						
9 weeks	1.02	1.02	0.62	1.50	1.43	0.93
15 weeks	1.18	0.93	0.62	1.65	1.45	0.76
Av. daily gain adjusted for feed intake, lb.						
9 weeks	1.03	1.04	0.72	1.36	1.35	1.00
15 weeks	1.11	0.99	0.81	1.40	1.33	0.94
Feed per lb. of gain						
9 weeks	3.84	3.62	5.16	3.58	3.29	3.59
15 weeks	4.17	4.22	5.18	3.83	3.64	4.06
No. of deaths						
9 weeks	0	0	3	0	0	2
15 weeks	0	2	6	0	0	6

[a] The weight at death was used as the final weight for pigs that died.

TABLE 4. PERFORMANCE DATA OF PIGS FED GRADED LEVELS OF FREE GOSSYPOL WITH TWO SOURCES OF PROTEIN

(EXPERIMENT II)

Source of protein	Cottonseed meal			Soybean meal		
Free gossypol level,%	0.00	0.02	0.04	0.00	0.02	0.04
No. of pigs per treatment	6	6	6	6	6	6
Av. initial weight, lb.	38	36	40	38	38	39
Av. final weight, lb.[a]	125	83	92	200	208	185
Av. daily feed intake, lb.						
8 weeks	2.77	2.14	2.52	4.17	4.03	3.85
16 weeks	3.43	2.22	2.76	5.22	5.17	4.76
Av. daily gain, lb.						
8 weeks	0.66	0.49	0.52	1.39	1.41	1.30
16 weeks	0.80	0.43	0.53	1.48	1.56	1.37
Av. daily gain adjusted for feed intake, lb.						
8 weeks	0.80	0.82	0.74	1.11	1.17	1.12
16 weeks	0.94	0.92	0.86	1.11	1.21	1.13
Feed per lb. of gain						
8 weeks	4.44	4.53	4.95	2.98	2.86	2.97
16 weeks	4.38	5.52	5.78	3.53	3.31	3.51
No. of deaths						
8 weeks	0	0	1	0	0	0
16 weeks	0	2	3	0	0	1

[a] The weight at death was used as the final weight for pigs that died.

The mean squares from the analysis of variance of Experiments I and II are shown in table 5.

Gossypol toxicity was not as severe in the second experiment as in the first. Only one pig receiving soybean meal rations died of gossypol poisoning while five of those receiving the cottonseed meal rations died. Clawson *et al.* (1959) have observed a higher mortality rate during the winter than during the summer months. Toxicity of pigs in the winter experiment appeared to be acute, showing very

TABLE 5. MEAN SQUARES FROM THE ANAYLSIS OF VARIANCE OF EXPERIMENTS I AND II

Source	d.f.	Mean square					
		Av. daily fd., int		A.D.G. (unadj.)		Fd./lb. of gain	
		9 weeks	15 weeks	9 weeks	15 weeks	9 weeks	15 weeks
Experiment I							
Replication	5	1.9**	1.5**	0.1**	0.1	1.4	1.7*
Meal (M)	1	7.5**	8.5**	1.4**	1.3**	4.6**	4.2**
Level (L)	2	6.6**	22.1**	0.9**	1.6**	2.7*	1.7
Linear (l)	1	12.2**	43.3**	1.4**	3.1**	2.7*	2.3
Quadratic (q)	1	1.0	0.9	0.3**	0.2*	2.8*	1.2
Meal x Level	2	0.9	1.3*	0.0	0.1*	1.6	0.5
M x L_l	1	1.8*	2.0*	0.1	0.2*	2.5	0.9
M x L_q	1	0.0	0.6	0.0	0.1	0.7	0.1
Error	25	0.4	0.3	0.1	0.1	0.6	0.6
		8 weeks	16 weeks	8 weeks	16 weeks	8 weeks	16 weeks
Experiment II							
Replication	5	0.5	0.6	0.1	0.1	0.2	0.2
Meal (M)	1	21.2**	45.4**	5.9**	7.0**	26.1**	28.4**
Level (L)	2	0.5	1.4*	0.1	0.1*	0.3	1.5
Linear (l)	1	0.5	1.9*	0.1	0.2**	0.4	2.9
Quadratic (q)	1	0.5	0.9	0.0	0.1	0.2	0.1
Meal x Level	2	0.3	1.2	0.1	0.2*	0.2	1.9
M x L_l	1	0.0	0.1	0.0	0.1	0.4	3.0
M x L_q	1	0.6	2.2*	0.1	0.3**	0.0	0.8
Error	25	0.2	0.4	0.1	0.1	0.2	0.9

* $P<0.05$.
** $P<0.01$.

few symptoms before death. Symptoms of toxicity in the summer experiment were more chronic in nature. Pigs tended to go off feed and gained very little before death. Another possible explanation of the lower mortality rate in the summer is that the actual level of free gossypol received by the pigs may have been lower in the summer experiment because of a greater loss or inactivation of free gossypol as a result of higher temperatures (Kupperman and Karon, 1955). The difference in gossypol content of the cottonseed meats used in Experiments I and II has previously been pointed out. The fact, that the protein level of the rations was reduced from 14.5 to 12.5% in Experiment I and was not reduced in Experiment II, may also account for a part of the difference in toxicity between experiments. A number of workers have shown a beneficial effect of increased protein level on resistance of pigs to gossypol toxicity (Hale and Lyman, 1957; Stevenson and Earle, 1947; Earle, 1959).

Soybean meal rations were consumed in larger amounts than were either peanut meal or cottonseed meal rations. Feed intake during the first few weeks of the experiments was less for animals fed peanut and cottonseed meal rations. It appears from this that the soybean meal rations were more palatable. However, this difference in feed intake between protein sources became greater as the experiments progressed. This marked difference between protein sources which occurred later may have resulted from the combined effect of palatability and amino acid deficiency or amino acid imbalances in the diet. Frazier *et al.* (1947) suggested that loss in appetite, which occurs during an amino acid deficiency, results from a general disturbance of the metabolism. This could have such a physiological effect on the animal as to temporarily affect appetite. Harper and Kumta (1959) have shown that amino acid imbalances cause a rapid reduction in feed intake and suggest that there is a decrease in the efficiency of utilization of all amino acids as a result of one limiting amino acid in the diet. Lysine is the amino acid most likely to be limited in cottonseed and peanut meal rations.

It is apparent from the data presented that free gossypol had an effect on the appetite, which was greater on the poorer quality protein sources. This is in agreement with other swine experiments reported by Clawson and co-workers (1957, 1959). Cabell and Earle (1956) have reported that poor feed consumption was one of the symptoms of gossypol toxicity in rats. Ferguson *et al.* (1959) observed a reduction of feed intake when diets of chickens contained gossypol. Free gossypol may have caused a disturbance of the animal's metabolism which could have resulted in reduced appetite and/or free gossypol may have affected the palatability of the ration.

Free gossypol, at the levels used in these experiments, appeared to have little effect on the feed efficiency of the soybean meal rations as measured by feed gain ratios. However, in the case of peanut and cottonseed meal rations, feed efficiency appeared to be reduced when free gossypol was added. Couch *et al.* (1955) reported that free gossypol at 0.06% or less in the total ration of chicks had no detrimental effects on growth rate or feed efficiency. Results of tests using 24 cottonseed meals fed to chicks (Eagle and Davies, 1957) showed no apparent correlation between feed efficiency and the free, bound, or total gossypol content of the diets.

Results of the digestion trial conducted during Experiment II showed that the soybean meal rations were more digestible than the cottonseed meal rations. The addition of free gossypol had no significant effect on the digestibility of dry matter, crude fiber, crude protein and nitrogen free extract (table 6). The apparent digestibility of ether extract was improved by the addition of free gossypol. This increase in apparent digestibility was probably a result of the added oil contained in the cottonseed meats, which is generally highly digestible, to obtain the 0.02 and 0.04% level of free gossypol.

Summary and Conclusions

The results of an investigation to determine the effect of protein source on toxicity of gossypol in swine rations are presented. Peanut and soybean meal were used as the sources of supplemental protein in Experiment I and cottonseed and soybean meal in Experiment II. Cottonseed meats were added to the rations containing each source of protein to obtain graded levels of free gossypol. Six pigs were individually fed each ration.

The toxicity of free gossypol, as measured by feed intake, gain and mortality of swine was influenced by both the source of protein and the level of free gossypol. There was a significant ($P<0.05$) protein-source x level-of-free-gossypol interaction associated with feed consumption and daily gain. Soybean

TABLE 6. MEAN DIGESTION COEFFICIENTS OBTAINED FROM PIGS FED GRADED LEVELS OF GOSSYPOL IN COMBINATION WITH TWO SOURCES OF PROTEIN (EXPERIMENT II)

Source of protein	Cottonseed meal			Soybean meal		
Free gossypol level, %	0.00[a]	0.02[b]	0.04[b]	0.00	0.02	0.04
Dry matter	76	78	76	83	83	82
Nitrogen	64	69	64	76	76	76
Ether extract	61	75	67	62	69	74
Crude fiber	13	24	13	33	22	19
Nitrogen free extract	86	87	86	90	90	90

[a] Contained approximately 0.0064 percent free gossypol, the amount present in the cottonseed meal.
[b] One pig on the high level of gossypol had died. One pig on the medium level of gossypol was showing signs of toxicity and was not used, because of lack of feed consumption. A missing plot formula was used to calculate values for these two missing observations.

meal rations gave superior performance to peanut or cottonseed meal rations at all levels of free gossypol.

Efficiency of feed utilization was not significantly affected by gossypol addition to the ration. The mortality rate was lower for pigs fed soybean meal rations than for pigs fed peanut or cottonseed meal rations.

Literature Cited

A.O.A.C. 1945. Official and tentative methods of analysis (6th ed.). Association of Official Agricultural Chemists. Washington, D. C.

Cabell, C. A. 1957. Effect of varying protein intake, source and lysine content on free gossypol tolerance by rat. Proc. 4th. Conf. on Processing as Related to Nutritive Value of Cottonseed Meal. Jan. 14–16:67.

Cabell, C. A. and I. P. Earle. 1956. Relation of amount and quality of protein in the diet to free gossypol tolerance by the rat. J. Am. Oil Chem. Soc. 33:416.

Clawson, A. J. and E. R. Barrick. 1957. Effect of protein source and gossypol level in the rations of growing pigs. Proc. 4th. Conf. on Processing as Related to Nutritive Value of Cottonseed Meal, Jan. 14–16:61.

Clawson, A. J., J. T. Reid, B. E. Sheffy and J. P. Willman. 1955. Use of chromium oxide in digestion studies with swine. J. Animal Sci. 14:700.

Clawson, A. J., F. H. Smith and E. R. Barrick. 1959. Cottonseed research with swine. Proc. 5th Conf. on Processing as Related to Nutritive Value of Cottonseed Meal. Jan. 19–20:53.

Couch, J. R., Wan-Yuin Chang and C. M. Lyman. 1955. The effect of free gossypol on chick growth. Poultry Sci. 34:178.

Eagle, E., H. F. Bialek, D. L. Davies and J. W. Brewer. 1956. Biological vs. chemical evaluation of toxicity and protein quality of cottonseed meals. J. Am. Oil Chem. Soc. 33:15.

Eagle, E. and D. L. Davies. 1957. Feed value and protein quality determination on cottonseed meals. J. Am. Oil Chem. Soc. 34:454.

Earle, I. P. 1959. Use of cottonseed meal in swine studies. Proc. 5th Conf. on Processing as Related to Nutritive Value of Cottonseed Meal. Jan. 19–20: 52.

Ferguson, T. M., J. R. Couch and R. H. Rigdon. 1959. Histopathological effect of gossypol. Proc. 5th Conf. on Processing as Related to Nutritive Value of Cottonseed Meal. Jan. 19–20:15.

Frazier, L. E., R. W. Wissler, C. H. Steffee, R. L. Woolridge and P. R. Cannon. 1947. Studies in amino acid utilization. I. The dietary utilization of mixtures of purified amino acids in protein-depleted adult albino rats. J. Nutr. 33:65.

Hale, Fred and C. M. Lyman. 1957. Effect of protein level in the ration on gossypol tolerance in growing-fattening pigs. J. Animal Sci. 16:364.

Harper, A. E. and U. S. Kumta. 1959. Amino acid balance and protein requirement. Fed. Proc. 18: 1136.

Heywang, B. W., H. R. Bird and R. P. Kupperman. 1952. The loss or inactivation of pure gossypol in a mixed diet. Poultry Sci. 31:35.

Kupperman, R. P. and M. L. Karon. 1955. Effect of time and temperature of storage on the free and total gossypol content of cottonseed meals. J. Am. Oil Chem. Soc. 32:54.

Schurch, A. F., E. W. Cramptom, S. R. Haskill and L. E. Lloyd. 1952. The use of chromium oxide in digestibility studies with pigs fed *ad libitum* in the barn. J. Animal Sci. 11:261.

Smith, A. M. 1955. Use of chromic oxide and plant chromogens for determining the intake of pasture herbage by grazing cows. M.S. thesis. Cornell University, Ithaca, New York.

Smith, F. H. 1946a. Estimation of gossypol in cottonseed meal and cottonseed meats. Ind. Eng. Chem., Anal. Ed. 18:43.

Smith, F. H. 1946b. Effect of acetic acid on the spectrometric estimation of gossypol in aqueous alcoholic solution. Ind. Eng. Chem., Anal. Ed. 18:656.

Smith, F. H. 1957. Toxicity of free gossypol in relation to protein of feed. Proc. 4th Conf. on Processing as Related to Nutritive Value of Cottonseed Meal. Jan. 14–16:66.

Smith, F. H. 1958. Spectrophotometric determination of total gossypol in cottonseed meal and cottonseed meats. J. Am. Oil Chem. Soc. 35:261.

Smith, F. H., C. T. Young, and F. W. Sherwood. 1958. Effect of bound gossypol on the growth-promoting properties of cottonseed, soybean and peanut meals. J. Nutr. 66:393.

Stevenson, J. W. and I. P. Earle. 1957. Protein—A modifying factor in gossypol toxicity. Feed Age 7:42.

INTRAMUSCULAR FAT DISTRIBUTION IN THE *LONGISSIMUS DORSI* OF PAIRED PORK LOINS [1]

Z. L. CARPENTER, R. W. BRAY, E. J. BRISKEY AND D. H. TRAEDER [2]

University of Wisconsin, Madison

A MAJOR problem in using single muscles in meat quality studies is the extreme variability in the fat distribution within the muscle. Weir (1953) found extreme variability in fat content within the *longissimus dorsi* muscle.

Although the relative importance of intramuscular fat content in relation to palatability is controversial at this time, the major portion of pork quality research includes qualitative or quantitative fat determinations.

The purpose of this study was to investigate the quantity of intramuscular fat in different loci of paired pork loins from carcasses varying in weight and fatness.

Experimental Procedure

Thirty-five paired pork loins from two weight groups of pork carcasses (220–250 lb.) and (135–180 lb.) were used in this study. The entire *longissimus dorsi* muscle from each side of the carcass was trimmed to remove all external fat. One-inch cross-sections of the *longissimus dorsi* adjacent to the 7th rib, 13th rib and 6th lumbar vertebra from each side provided samples for each position within the muscle. The remaining portions of the *longissimus dorsi* muscle from each side of the carcass were combined to form the composite sample. The samples were ground three times, frozen and subsequently extracted with diethyl ether for 16 hours. The percent extract is reported as the fat content on a dry weight basis.

The size and number of intramuscular fat cells were histologically studied in the loins from the lightweight group of carcasses. A sample from each of the three one-inch cross-sections from the left loin was fixed in osmic acid for 2 hours and sections 8 microns in thickness were subjectively scored on the basis of size of fat cells. The scores for size of the fat cells ranged from 1 to 5 with the latter including those samples containing larger fat cells. These scores were based on reference photomicrographic standards. The number of fat cells in each of the three samples from each loin was determined from the microscopic slides.

Results and Discussion

The fat content (dry weight basis) in the composite samples from the 20 heavy carcasses ranged from 11.32 to 35.49%, while the 15 light carcasses contained 15.37 to 41.20% extractable fat. The range was approximately the same in both groups, however, the light carcasses contained a significantly higher average percent of intramuscular fat than did the heavy carcasses.

The means of the percents of extractable fat from the various areas of the loins from the two weight groups are given in table 1. The composite sample of the left loin in each group contained a nonsignificantly higher extractable fat content than did the right loin. Highly significant differences in extractable fat were found among the three positions in the loin within each weight group. The 6th lumbar position in both weight groups contained a significantly higher percentage of fat than the other two positions, while the 13th rib location contained the least in each case.

Duncan's multiple range test of the various positions within the loin indicates the areas where longitudinal variability exists (table 2). Any two means not underscored by the same line are significantly different at the 0.05 level. The 7th rib and 13th rib samples (lightweight group) were not statistically different from the composite average, while the 6th lumbar position was significantly different from the composite sample. The data from the heavy carcasses do not show that the 7th rib and 13th rib samples were different from the composite average; however, the 6th lumbar fat content was significantly higher than the other positions. Therefore, the results indicate that possibly a valid area for the estimation of the intramuscular fat content of the entire *longis-*

[1] Published with the approval of the Director of the Wisconsin Agricultural Experiment Station.

[2] Department of Animal Husbandry.

TABLE 1. MEANS OF PERCENT INTRAMUSCULAR FAT IN PAIRED PORK LOINS [a]

Weight group	Left loin				Right loin			
	6th lumbar	13th rib	7th rib	Composite	6th lumbar	13th rib	7th rib	Composite
Heavy	29.01	17.97	24.11	21.57	26.99	18.08	23.29	21.10
Light	33.32	22.35	29.13	26.72	34.10	22.23	30.50	25.57

[a] All chemical data are expressed on the dry weight basis.

simus dorsi would be somewhere between the 7th and 13th ribs, even though variation in fat content also exists in this section of the loin.

These data are from hogs 6–7 months and 10–12 months of age and tend to support the data reported by McMeekan (1940), which show that the anterior and posterior portions of the loin of the growing pig contain a higher percent of total fat than the middle portion.

TABLE 2. DUNCAN'S MULTIPLE RANGE TEST —COMPARISONS OF INTRAMUSCULAR FAT CONTENT AMONG LOIN POSITIONS [a]

Weight group	13th rib average	Composite average	7th rib average	6th lumbar average
Heavy	18.03	21.34	23.70	28.08
Light	22.31	26.01	30.15	33.71

[a] Any two means not underscored by the same line are significantly different at the 0.05 level.

The data submitted in this report indicate that, somewhere between the 28-week age level and the 40 to 48-week age level, the percent of total fat decreases. This is in agreement with reports of Kropf (1956) and Kelly *et al.* (1957) which show that the younger, lighter weight carcasses contained higher percents of extractable intramuscular fat.

Table 3 presents correlation coefficients between positions for extractable fat content within the *longissimus dorsi* muscle. The correlations between the intramuscular fat content of all positions and the composite samples were highly significant for both weight groups. Each position in the *longissimus dorsi* muscle was also highly correlated with the other positions in the loin in regard to extractable fat content.

Length, weight and backfat measurements were obtained on all of the carcasses. Corre-

TABLE 3. SIMPLE CORRELATIONS OF INTRAMUSCULAR FAT DISTRIBUTION IN THE *LONGISSIMUS DORSI* [a]

	Light carcasses				
	Composite right	Composite left	7th rib average	13th rib average	6th lumbar average
Composite average	0.98	0.97	0.69	0.75	0.93
7th rib, right	0.88	....	....	....	....
13th rib, right	0.80	....	....	....	....
6th lumbar, right	0.87	....	....	....	....
Composite, left	0.88	....	....	....	....
7th rib, left	....	0.83	....	....	....
13th rib, left	....	0.86	....	....	....
6th lumbar, left	....	0.85	....	....	....
7th rib, average	....	....	....	0.81	....
6th lumbar, average	....	....	0.62	....	....
	Heavy carcasses				
	Composite right	Composite left	7th rib average	13th rib average	6th lumbar average
Composite average	0.99	0.99	0.89	0.95	0.93
7th rib, right	0.91	....	....	....	....
13th rib, right	0.98	....	....	....	....
6th lumbar, right	0.96	....	....	....	....
Composite, left	0.96	....	....	....	....
7th rib, left	....	0.85	....	....	....
13th rib, left	....	0.92	....	....	....
6th lumbar, left	....	0.85	....	....	....
7th rib, average	....	....	....	0.87	....
6th lumbar, average	....	....	0.84	0.92	....

[a] All correlations are highly significant.

lation coefficients of these physical measurements with extractable fat in the various areas of the *longissimus dorsi* are presented in table 4. The data from lightweight carcasses show

TABLE 4. ASSOCIATION OF INTRAMUSCULAR FAT WITH CERTAIN PHYSICAL MEASUREMENTS

Light carcasses			
Simple correlations	Length	Weight	Backfat
Weight	0.89**	....	....
Backfat	—.07	0.64**	....
7th rib av., % Fat MFB	—.13	0.10	0.13
13th rib av., % Fat MFB	—.21	0.11	0.04
6th lumbar av., % Fat MFB	—.17	0.12	0.04
Composite av., % Fat MFB	—.39	0.07	0.06
Heavy carcasses			
Simple correlations	Length	Weight	Backfat
Weight	0.62**	....	....
Backfat	—.17	0.31	....
7th rib av., % Fat MFB	—.06	—.19	—.17
13 rib av., % Fat MFB	—.06	—.06	0.02
6th lumbar av., % Fat MFB	—.06	—.03	0.16
Composite av., % Fat MFB	—.03	—.04	—.06

** Significant at the 0.01 level.

a highly significant correlation between weight and backfat thickness while the correlation between weight and intramuscular fat content of the *longissimus dorsi* muscle was low. It is interesting to note, however, that the heavy carcasses exhibited a relatively low correlation between weight and backfat thickness.

The subjective scores for fat distribution, as studied microscopically, show that with an increase in extractable fat content there was a highly significant increase in finely dispersed fat cells. The size of the fat cells compared to the fat content showed a highly significant correlation of —.81. There was a larger number of more finely dispersed adipose cells in the 6th lumbar sample than in the 7th or 13th rib samples.

Summary

It can be concluded from this study that extreme variation exists between the fat content of different areas of the *longissimus dorsi* muscle of pork carcasses. From these data one can readily see the importance of following a rigidly standardized procedure when obtaining samples for use in pork quality research. The data indicate that this standardization is probably more important than the problem of which position to use as an estimate of the composite, because on a relative basis all of the correlations are quite highly associated with the composite samples. Indications were that the size of the intramuscular fat cells was smaller in muscles containing a higher percentage of the extractable fat.

Literature Cited

Kelly, R. F., R. W. Bray and P. H. Phillips, 1957. The influence of chlortetracycline supplementation of the ration on distribution, quantity and quality of fat deposited in swine. I. Metabolic effects in relation to carcass composition. J. Animal Sci. 16:74.

Kropf, D. H. 1956. The effect of protein quality and supplementation of swine rations with lysine and tryptophan upon nitrogen metabolism growth and carcass composition of swine. Ph.D. Thesis. University of Wisconsin, Madison, Wis.

McMeekan, C. P. 1940. Growth and development in the pig, with special reference to carcass quality characters. J. Agr. Sci. 30:276.

Weir, C. E. 1953. Variation in tenderness in the *longissimus dorsi* muscle of pork. Food Tech. 7:500.

UTILIZATION OF PHYTIN PHOSPHORUS IN WHEAT BRAN BY SHEEP

LeGrande C. Ellis and Allen D. Tillman[1]

Oklahoma State University, Stillwater

MUCH of the phosphorus in seeds and their by-products occurs as salts of the hexaphosphoric ester of inositol called phytin. Calcium, magnesium, potassium and other cations form salts of this complex which are poorly utilized by non-ruminant animals (Gillis *et al.*, 1953; Chapman *et al.*, 1955; Gillis *et al.*, 1957) but ruminants appear to utilize phytin satisfactorily (Jordan *et al.*, 1906; Mathur, 1953; Tillman and Brethour, 1958). Reid *et al.* (1947) have shown that rapid hydrolysis of phytin occurs in the rumen and Raun *et al.* (1956) found that phytase was produced by rumen microorganisms. This suggests that the hydrolysis of phytin in the rumen is independent of the phytase found in the feed. Various factors influence the amount of hydrolysis taking place in the gastrointestinal tract of ruminants, however, and phytin has been detected in the undigested material of the feces (Reid *et al.*, 1947; Mathur, 1953). The purpose of this study was to investigate the availability of phosphorus in wheat bran fed to sheep.

Experimental Procedure

The composition of the basal diet is shown in table 1. Approximately 91% of the phosphorus in the diet was supplied by the wheat bran with the remainder coming from the supplement.

Four wethers, 5–6 months of age and weighing from 53–60 lb. each, were placed in metabolism stalls described by Briggs and Gallup (1948). Each sheep was fed 350 gm. of the basal diet twice daily during the 14-day preliminary and 7-day collection periods. The sheep were injected with one millicurie of phosphorus-32 at the onset of the collection period and subsequent daily collections of feces and urine were made. Inorganic phosphorus analyses were made using the method of Fiske and SubbaRow (1925). Radiophosphorus was determined using a thin mica window Geiger-Mueller tube and scaler. Calculations of fecal endogenous phosphorus and true digestibility were made using the isotope dilution method described by Kleiber *et al.* (1951) which was modified by Hansard (1956) to permit a single injection of the isotope. The calcium content of the ration was calculated using figures presented by Morrison (1956).

Results and Discussions

The results of the digestion trial (table 2) indicate that about one-fourth of the phosphorus from the ration was utilized. Appreciable amounts of phytin must have been digested since approximately 91% of the dietary phosphorus came from the wheat bran. The digestibility of phosphorus from this diet, high in phytin, is somewhat lower than the data previously reported by Reid *et al.* (1947), Raun *et al.* (1956) and Tillman and Brethour (1958). On the basis of their findings, Reid *et al.* (1947) suggested that finer particles of bran may pass from the rumen before complete hydrolysis of phytin could take place. Examination of the feces indicated that incomplete digestion of the wheat bran had taken place. Raun *et al.* (1956), using

TABLE 1. COMPOSITION OF BASAL DIET

Ingredient	Composition	Phosphorus
	%	%
Wheat bran	77.78	1.07
Supplement	22.22	0.11
$CaCO_3$	2.44	....
NaCl	0.50	....
Quadrex[a]	0.06	....
Cerelose	9.61	....
Starch	9.61	....
Total	100.00	1.18

[1] Department of Physiology and Pharmacology and the Department of Animal Husbandry, respectively. Published with the approval of the director of the Oklahoma Agricultural Experiment Station.

[a] Quadrex, NOPCO Chemical Co., Harrison, New Jersey. Contained 20,000 I.U. of Vitamin A and 2,500 USP units of Vitamin D_3 per gram.

TABLE 2. DIGESTIBILITY, ENDOGENOUS EXCRETION AND DAILY BALANCE OF PHOSPHORUS IN WHEAT BRAN

	Values	Standard error
Phosphorus		
Intake, gm.	8.20	....
Wheat bran, gm.	7.46	....
Supplement, gm.	0.74	....
Excretion, gm.	8.36	....
Feces, gm.	6.99	....
Urine, gm.	1.37	....
Fecal endogenous, gm.	0.88	0.10
Urine, % of fecal	19.60	....
Retained, % of intake	−1.95	....
Endogenous, % of fecal	10.73	....
Apparent digestibility, %	14.75	3.03
True digestibility, %	25.49	3.26

washed suspensions of rumen microorganism, observed a decrease in the percent hydrolysis of phytin as the substrate concentration was increased even though the total amount of phosphorus liberated was greater. This may explain in part why the digestibility of phosphorus in this trial was lower than that reported by other workers.

The endogenous phosphorus is somewhat lower than the values reported in cattle by Kleiber *et al.* (1951), who found that endogenous phosphorus often exceeds the undigested phosphorus of the feces. The urinary phosphorus in this trial is much higher than the values they reported. They also found the urinary phosphorus in cattle amounted to less than 1% of the phosphorus excreted in the feces. This difference might be explained partially by the high phosphorus intake of the sheep in this experiment. The phosphorus intake of these sheep was roughly 3.4 times the intake reported by Tillman and Brethour (1958).

Calculations made from the data collected on days 6 and 7 of the collection period gave almost identical values. These calculations were used to determine the validity of the results. They indicate that only one injection of phosphorus-32 is necessary for the determination of endogenous phosphorus and true digestibility, as suggested by Hansard (1956).

Summary

Four wethers, 5–6 months of age and weighing 53–60 lb. each, were used to determine the availability of phosphorus in wheat bran using conventional and isotope procedures. Fecal endogenous phosphorus was determined by the isotope dilution procedure, using a single injection of phosphorus-32 at the onset of the collection period. The apparent and true digestibilities of phosphorus were, respectively, 14.75 and 25.49%. The urinary phosphorus values were abnormally high in all animals. The specific activity of the urinary phosphorus was essentially the same as that of the plasma, indicating that the phosphorus of the urine had been available for body utilization.

Literature Cited

Briggs, H. H. and W. D. Gallup. 1948. Metabolism stalls for wethers and steers. J. Animal Sci. 8:479.

Chapman, H. L., J. Kastelic, G. C. Ashton and D. V. Catron. 1955. A comparison of phosphorus from different sources for growing and finishing swine. J. Animal Sci. 14:1073.

Fiske, C. H. and Y. SubbaRow. 1925. The colorimetric determination of phorphorus. J. Biol. Chem. 66:375.

Gillis, M. B., K. W. Keane and R. A. Collins. 1957. Comparative metabolism of phytate and inorganic P^{32} by chicks and poults. J. Nutr. 62:13.

Gillis, M. B., L. C. Norris and G. F. Heuser. 1953. Phosphorus metabolism and requirements of hens. Poul. Sci. 32:977.

Hansard, S. L. 1956. Tracer methods in mineral nutrition research. AEC-TID 7512:31.

Jordan, W. H., E. B. Hart and A. J. Patten. 1906. A study of the metabolism and physiological effects of certain phosphorus compounds with milk cows. Am. J. Physiol. 16:268.

Kleiber, Max, A. H. Smith, N. P. Ralston and A. L. Black. 1951. Radiophosphorus as tracer for measuring endogenous phosphorus in cows' feces. J. Nutr. 45:253.

Mathur, N. L. 1953. Assimilation of phytin phosphorus by dairy cows. Indian J. Vet. Sci. 4:243.

Morrison, F. B. 1956. Feeds and Feeding. (2nd ed.). Morrison Publishing Co., Ithaca, New York.

Raun, A., E. Cheng and W. Burroughs. 1956. Phytate Phosphorus hydrolysis and availability to rumen microorganisms. J. Agr. Food Chem. 4:869.

Reid, R. L., M. C. Franklin and E. G. Hallsworth. 1947. The utilization of phytate phosphorus by sheep. Australian Vet. J. 23:136.

Tillman, A. D. and J. R. Brethour. 1958. Utilization of phytin phosphorus by sheep. J. Animal Sci. 17:104.

EARLY PREGNANCY LOSS IN SHEEP AT AMBIENT TEMPERATURES OF 70° AND 90° F. AS DETERMINED BY EMBRYO TRANSFER [1]

C. W. ALLISTON [2] AND L. C. ULBERG

North Carolina State College, Raleigh

HIGH ambient temperature has been shown to cause a loss of potential young in mammals (Dutt, 1960; Macfarlane *et al.*, 1959; Ulberg, 1958). In sheep this loss is a result of increased embryonic death as well as a lowering of fertilization rate (Dutt *et al.*, 1959; Alliston *et al.*, 1961). An understanding of the mechanism(s) of the embryonic aberration requires establishment of the stage in the reproductive process during which damage to or death of the embryo occurs.

This study was initiated in an attempt to determine, through the use of a technique of embryo transfer, the time, or range of time, during which the detrimental effects of high temperature are exerted upon the embryo and to establish, if possible, the importance of endometrial function in the cause of this death.

Materials and Methods

Embryos were recovered from the oviducts of donors and transferred to uteri of recipients using grade "black-faced" ewes which had been wintered in Ohio after shipment from the northwestern area of the United States. Fifty yearling ewes were received in May, 1958 and another 50 of the same breeding and history a year later. Twenty-five ewes from the 1958 shipment were used for the second year during the 1959 breeding season. Preparatory to the experimental period all ewes were placed in a pasture approximately two acres in size and fed approximately 0.75 lb. of a grain mixture and a small amount of hay per day. Shade and water were available at all times. Normality of the estrous cycles was established by daily observation with a vasectomized or aproned teaser ram.

During the first portion of the 1958 breeding season the transfer of embryos was made between individuals where onset of estrus was spontaneously synchronized to within 24 hours. Twelve days after occurrence of estrus ewes were paired by date of estrus, removed from the pasture and placed in one of two environmental temperature control chambers maintained at either 70° F. or 90° F. with 65% relative humidity.

During the latter portion of 1958 and throughout 1959, exogenous hormones were used to control ovarian activity which synchronized estrus preparatory to transfers. Ewes having approximately the same date of estrus were paired and given 14 daily subcutaneous injections of 10 mg. of progesterone in 2 cc. of sesame oil. Where possible, injections were begun within one week of the last observed estrus. Forty-eight hours after the last progesterone injection, 750 I.U. of pregnant mare serum (PMS) were injected into the semitendinosus. This method of control of ovarian activity has been reviewed by Gordon (1958a, b). Ewes were placed in the chambers five days before the predicted date of estrus.

While in the chambers ewes received approximately 0.75 lb. of a good quality hay and water, *ad libitum*, from open containers which had approximated the temperature of the room. Observations for estrus were made twice daily. Rectal temperatures and respiration rates were observed on all animals at four 12-hour intervals beginning 48 hours after allocation to the chambers (pre-operative period). A rectal thermometer was inserted approximately 2½ in. into the rectum to determine rectal temperature and respiration rate was estimated by counting chest movements for a 30-second interval. A comparable series of four observations was made after the transfer had been performed (post-operative period). Ewes utilized in more than

[1] From the Department of Animal Industry. Published with the approval of the Director of Research, North Carolina Agricultural Experiment Station as paper No. 1292 of the Journal Series. This investigation was supported, in part, by a PHS Research Grant, RG-5458 from the Division of General Medical Sciences, Public Health Service. The following persons assisted in collection of portions of the data: H. A. Poston, Mrs. Doris Koontz, and C. O. Woody. The assistance of H. F. Lucas and Charles Rohde with portions of the statistical analysis is acknowledged. The pregnant mare serum (Gonadogen) was supplied through the courtesy of R. A. Gessert, Upjohn Co., Kalamazoo, Michigan.

[2] Present Address: Department of Zoology, North Carolina State College, Raleigh.

one transfer had a minimum of one estrous cycle of normal length (15 to 19 days) between successive transfers.

For convenience in tabulation and discussion the following symbolism has been adopted for the three types of transfers: (1) 70° F.→ 70° F.; (2) 90° F.→ 70° F.; and (3) 70° F. →90° F. The first value refers to the ambient temperature for the donor and the second value for that of the recipient. No transfers were performed where both donor and recipient were maintained at 90° F. as previous experience (Alliston *et al.*, 1961) had indicated that reproductive performance at that temperature is low. Ewes were allotted to the chambers so that equal numbers of the three types of transfers were made over a given period of time.

All donor ewes were bred by natural service 12 hours after estrus was first detected and rebred at 12-hour intervals until estrus had ended. Only rams known to have high quality semen, as evaluated by sperm concentration and progressive motility, were used. Transfers were performed between 60 and 84 hours after first mating, usually at about 72 hours. This is about the time the embryos are expected to enter the uterus. Both donor and recipient were lightly anesthetized with a sodium pentobarbital solution and the donor's reproductive tract exposed through a midventral incision immediately anterior to the udder. When necessary, ether was used to deepen anesthesia during surgery. Embryos were recovered in the 2- to 32-cell stage, with the majority in the 8-cell stage. Uncleaved ova were not transferred during this portion of the study.

Two methods of embryo recovery were used. During the first portion of the 1958 breeding season embryos were recovered from the excised oviduct of the donor ewe by flushing it with sterile blood serum previously collected from the donor, frozen for storage, and warmed to approximately 102° F. at the time of use. A blunt 15-gauge hypodermic needle was attached to a syringe inserted into the infundibular end of the oviduct and 5 to 10 cc. of the serum gently forced through the oviduct into sterile watch glasses previously warmed to body temperature.

During the latter portion of 1958 and throughout 1959 the technique employed was a modification of one used by Hunter *et al.* (1955). Embryos were recovered from intact ewes with a medium of equal parts of modified Krebs solution (Lardy and Phillips, 1943) and sterile blood serum. A change in the medium was made in an attempt to avoid indentation of the zona pellucida. Recovery was accomplished by inserting polyethylene tubing into the infundibular end of the oviduct and clamping it into place with a wound clip applicator. Tubing having an outside diameter of 0.095 in. and an inside diameter of 0.066 in. was most commonly used. Five to ten cc. of the recovery media was then injected into the uterine horn which had been temporarily clamped between the thumb and forefinger to prevent flow of the fluid into the uterine body. The fluid was forced from the uterus, through the oviduct and tubing into sterile, warmed watch glasses. Uncleaved but otherwise normal ova were transferred during this portion of the study.

Where multiple ovulations occurred and more than one embryo was recovered from the same oviduct, one embryo was redeposited in the opposite uterine horn of the donor. Where there was one or more ovulations on each ovary, no attempt was made to recover embryos from one oviduct. When recovery was unsuccessful, the ewe was continued on experiment and retained in the designated chamber.

Upon recovery of an embryo that was considered to be normal, the reproductive tract of the recipient was exposed through a midventral incision and the number and location of ovulations noted. After examination under a stereomicroscope (9 to 60x) the embryo was picked up from the watch glass by means of a capillary tube prepared from 6 mm. soft glass tubing. The end of the capillary was broken to a point and fire polished to facilitate penetration of the uterine tissue of the recipient. With the embryo in the capillary, the tube was inserted into the lumen of the uterus from the antimesometrial border. With the tip near the tubo-uterine junction the capillary was evacuated by a rolling action of the thumb and forefinger on a one inch piece of rubber tubing slipped over the large end of the tube. Where possible, no air was forced into the uterus and only a small amount (approximately 0.005 cc.) of the flushing solution was injected with the embryo. The average elapsed time between recovery of the embryo and its deposition in the recipient was approximately 12 minutes when the incision was not made in the recipient until the embryo was recovered. This time was reduced to approximately 6 minutes when the incision was also made in the recipient prior to recovery of the embryo.

All ewes having a potential embryo within her reproductive tract remained in the chamber until estrus was detected or a laporatomy

was performed for pregnancy diagnosis 25 to 30 days after estrus. Amnionic resiliency was indicative of a normal pregnancy. Rhythmic recurrence of estrus was considered to be adequate evidence for an unsuccessful transfer. Observations on embryo survival were therefore made on four types of embryos: (1) Those transferred between different animals; (2) those transferred within the same animal; (3) non-transferred embryos; and (4) embryos that were not recovered by flushing an intact oviduct.

Results and Discussion

Rectal Temperature and Respiration Rate. An increase in body temperature and respiration rate at elevated ambient temperatures has been reported by a number of investigators in many species. Such increases may be a general indication of the degree of stress imposed on the animal by high ambient temperatures.

A least squares analysis was used because of the disproportionate numbers with respect to the year-temperature classification data. Primary interest was in the effects of ambient temperature; hence the analysis of variance was run adjusting temperature and pre- and post-operative periods (P) x temperature (T) interaction for years (Y) and P x Y interaction respectively. The table of means (table 1) is adjusted to show the temperature and P x T effects after elimination of year and P x Y effects. Differences between temperature groups are highly significant ($P<0.01$). Differences in pre- and post-operative rectal temperatures are not significant.

Ovulation, Fertilization and Normality of Ova. Temperatures used in this study did not inhibit estrus as was observed by Chang and Fernandez-Cano (1959) in rats at 103° F. or significantly alter ovulation rate (table 2).

TABLE 1. ADJUSTED MEAN RECTAL TEMPERATURES AND RESPIRATION RATES OF EWES MAINTAINED AT 70° F. AND 90° F.

	Ambient temperature group[a]	
	70° F.	90° F.
Rectal temperature (° F.)		
Pre-operative	102.0	103.9
Post-operative	102.2	103.8
Average	102.1	103.9**
Respiration rate per minute		
Pre-operative	61.5	126.8
Post-operative	46.4	126.5
Average	53.9	126.7**

[a] 70° F. and 90° F. groups consisted of 91 and 49 ewes, respectively. Four pre-operative and four post-operative observations were made on each animal.
** $P<0.01$.

High ambient temperature might affect either the production or release of an ovum from the follicle, or its entry into or passage through the oviduct. Such effects might be reflected in the percent of ova recovered (table 2), assuming one ovum is produced per corpus luteum. The recovery rates for ewes maintained at 70° F. and 90° F. were 81% and 74% respectively. These differences are not significant. Difference in recovery rate, between temperature groups, was greatest in 1958 where recovery was from an excised oviduct and a small portion of the uterine horn. When recovery was made from the intact animal, a greater portion of the uterine horn was flushed. Therefore, the possibility exists that the speed with which the embryo travels through the oviduct is increased in ewes maintained at 90° F. Should this premise be correct, asynchrony between embryo and endometrial development might conceivably result in embryonic mortality due to "immature" embryos reaching the uterus. The necessity of synchronization of estrus between donor and recipient animals has been established in

TABLE 2. OVULATION RATE AND CLASSFICATION OF OVA AND EMBRYOS FROM EWES MAINTAINED AT AMBIENT TEMPERATURES OF 70° F. AND 90° F. (3 DAYS POST-MATING)

Item	Ambient temperature			
	70° F.		90° F.	
Year	1958	1959	1958	1959
No. ewes	26	34	16	20
No. ovulations (ovulation rate)	34 (1.3)	59 (1.7)	22 (1.4)	35 (1.8)
Ova or embryos recovered/attempts	31/33 (94%)	38/52 (73%)	15/21 (71%)	24/32 (75%)
Fertilized ova/ova recovered	25/31 (81%)	36/38 (95%)	9/15 (60%)	14/24 (58%)
Abnormal ova[a]/ova recovered	6/31 (19%)	1/38 (03%)	1/15 (07%)	2/24 (08%)

[a] Abnormal ova had indented or ruptured zona pellucida, degenerated blastomeres or vitelline membranes or similar conditions. Both fertilized or unfertilized ova are included.

embryo transfers and would tend to support this possibility. For example, McLaren and Michie (1956) obtained the lowest percent of successful transfers in mice where the donor was two and one-half days and recipients were three and one-half days post-coitus, and the highest percent of successful transfers where the donor was three and one-half days and the recipient was two and one-half days post-coitus.

A lower percent of the recovered ova were fertilized from donor ewes in the 90° F. group ($P<0.01$). This is in accord with previous observations (Dutt *et al.*, 1959; Alliston *et al.*, 1961). However, there does not appear to be information available that would indicate the physiological mechanism of this fertilization failure. The fertilization failure might, for example, be due to a sperm's inability to penetrate the ovum or to the effect of the uterus on the sperm after its deposition in the female reproductive tract.

In an attempt to make a further preliminary evaluation of the effects of the experimental temperatures upon the ova or embryos by 3 days post-estrus they were classified on the basis of morphological structure. An abnormal ovum or early embryo refers to one with an indented or ruptured zona pellucida, degenerated blastomeres or vitelline membranes, or similar abnormalities such as those described by Dutt (1954) and Laffey and Hart (1959). The difference between temperature groups for ova or embryos so classified (table 2) is not significant.

Normality of Embryos as Measured by Between Ewe Transfers. In an attempt to obtain a more objective measure of "normality", embryos were transferred from the oviduct of the donor to the uterus of the recipient at about the time the embryo normally enters the uterus. Continued development is considered as a measure of normality.

There is a highly significant ($P<0.01$) increase in the percent of embryonic death in 90→70° F. transfers when compared with those in 70→70° F. transfers (table 3). This failure of embryos, which originate in ewes subjected to a constant high (90° F.) temperature, to develop in uteri known to be capable of supporting growth indicates that irreversible damage has been done to that embryo prior to 3 days after mating. This damage was not apparent by microscopic examination at the time of transfer.

It should not be implied, however, that all damage, due to high ambient temperature has been done by 3 days after mating. The percent of successful 70→90° F. transfers was intermediate between the other types (table 3) and significantly lower than 70→70° F. transfers ($P<0.05$). This indicates that some detrimental effects of high temperature, as used in this study, can also occur after the embryo reaches the uterus. Yeates (1956) has observed that birth weights of lambs were lowered in ewes exposed to temperatures of 112° F. for 7 hours per day. In general, however, evidence indicates that high temperature exerts its greatest effect early in the gestation period.

The Effect of Transfer on Embryonic Survival. Results of "within animal" observations are summarized in table 4. Nontransferred embryos refer to those on the side having corpora lutea (CL) for which no recovery was attempted. The assumption was made that one ovum was produced per CL. Even with a limited number of this type embryo a significant reduction in diagnosed pregnancies was observed in ewes maintained at 90° F. as compared with ewes maintained at 70° F. ($P<0.05$). Similar trends were noted between temperature groups (though not significant) where apparently normal embryos were transferred within the same animal and where

TABLE 3. SUMMARY OF OBSERVATIONS ON "BETWEEN ANIMAL" EMBRYO TRANSFERS (25–30 DAYS POST-MATING)

Item	Year	Ambient temperature for donor ⟶ recipient: 70⟶70° F.	70⟶90° F.	90⟶70° F.
"Normal" embryo[a]	1958	5/11 (45.5%)	5/11 (45.5%)	0/9 (0.0%)
	1959	8/12 (66.7%)	1/14 (7.1%)	2/12 (16.7%)
	Total	13/23 (56.5%)	6/25 (24.0%)	2/21 (9.5%)
Uncleaved ova[b]	1959	.....	0/1 (0.0%)	0/5 (0.0%)
	Total	.....	0/1 (0.0%)	0/5 (0.0%)

[a] 2–32 cells without apparent signs of degeneration.
[b] Uncleaved by 3 days post-estrus.

TABLE 4. SUMMARY OF OBSERVATIONS ON "WITHIN ANIMAL" EMBRYO TRANSFERS AND NONTRANSFERRED EMBRYOS

Item	Year	Ambient temperature of ewe 70° F.	90° F.
Nontransferred embryo[a] (pregnancies/CL)	1958	.....	0/1 (0.0%)
	1959	5/7 (71.4%)	0/3 (0.0%)
	Total	5/7 (71.4%)	0/4 (0.0%)*
"Normal" embryo transfer (success/attempts)	1958	1/1 (100.0%)	.....
	1959	5/7 (71.4%)	0/2 (0.0%)
	Total	6/8 (75.0%)	0/2 (0.0%)
Uncleaved ova transfer (success/attempts)	1958	.....	.....
	1959	.....	0/3 (0.0%)
	Total	.....	0/3 (0.0%)
Nonrecovered embryo[b]	1958	.....	.....
	1959	3/13 (23.1%)	0/8 (0.0%)
	Total	3/13 (23.1%)	0/8 (0.0%)

[a] Copora lutea for which no recovery was attempted.
[b] Refers to an ovulation for which there was no embryo recovered by flushing an intact oviduct.
* $P<.05$.

embryos were not recovered by the intact recovery method (table 4).

There was no reduction in percent of pregnancies when "within animal" transfers were compared with nontransferred embryos in the 70° F. group. Therefore, the transfer technique apparently did not affect embryo viability. However, the possibility exists that under certain conditions an interaction between treatment and transfer could become a factor. This might occur where one of the experimental conditions produced a viable but "weak" embryo that could not survive a transfer but could develop normally if not transferred. Although not significant, fewer transfers were successful in 70→70° F. "between animal" transfers than "within animal" transfers in the 70° F. group, suggesting the possibility of some degree of antagonism between maternal tissues and "foreign" embryos.

Summary

Early embryo development in ewes maintained in ambient temperatures of 70° F. or 90° F. was studied by means of embryo transfers. Transfers were performed approximately 72 hours after onset of estrus and successful transfers were verified by a laporatomy performed 25–30 days later.

Where both donor and recipient were maintained at 70° F., 13 of 23 (56.5%) "between animal" transfers were successful as compared with 2 of 21 (9.5%) where donor and recipient were maintained at 90° F. and 70° F. respectively. Therefore, some detrimental action had occurred by 3 days after onset of estrus in ewes at 90° F. Although morphological differences were not apparent at the time of transfer, embryonic death occurred at a later stage of development in uteri known to be capable of supporting embryonic growth. Where embryos were transferred from donor to recipient ewes maintained at 70° F. and 90° F. respectively, 6 of 25 (24.0%) transfers were successful.

To evaluate possible harmful effects of transfer, embryos were either not transferred or were replaced in the original donor when multiple ovulations occurred. Five of seven (71.4%) and none of four non-transferred embryos continued development in 70° F. and 90° F. groups respectively, assuming one embryo was produced per corpus luteum. Six of eight (75.0%) "within animal" transfers were successful in the 70° F. group but no pregnancies resulted from two such transfers in the 90° F. group.

Literature Cited

Alliston, C. W., G. E. Egli and L. C. Ulberg. 1961. Loss of potential young in the ewe due to high ambient temperature. J. Applied Physiol. 18:253–256.

Chang, M. C. and Luis Fernandez-Cano. 1959. Effects of short changes of environmental temperature and low atmospheric pressure on the ovulation of rats. Am. J. Physiol. 196:653.

Dutt, R. H. 1954. Fertility rate and embryonic death loss in ewes early in the breeding season. J. Animal Sci. 13:465.

Dutt, R. H. 1960. Temperature and light as factors in reproduction among farm animals. J. Dairy Sci. (Supplement, April, 1960) 43:123. Proc. IV Biennial Symposium on Animal Reproduction.

Dutt, R. H., E. F. Ellington and W. W. Carlton. 1959. Fertilization rate and early embryo survival in sheared and unsheared ewes following exposure to elevated air temperature. J. Animal Sci. 18:1308.

Gordon, I. 1958a. The use of progesterone and serum gonadotrophin (P.M.S.) in the control of fertility in sheep. I. The hormonal augmentation of fertility in the ewe during the breeding season. J. Agr. Sci. 50:123.

Gordon, I. 1958b. The use of progesterone and serum gonadotrophin (P.M.S.) in the control of fertility in sheep. II. Studies in the extra-seasonal production of lambs. J. Agr. Sci. 50:152.

Hunter, G. L., C. E. Adams and L. E. Rowson. 1955. Inter-breed ovum transfer in sheep. J. Agr. Sci. 46:143.

Laffey, N. and D. S. Hart. 1959. Embryonic loss from late breeding season mating of ewes. New Zealand J. Agr. Res. 2:1159.

Lardy, H. A. and P. H. Phillips. 1943. Effect of pH and certain electrolytes on the metabolism of ejaculated spermatozoa. Am. J. Physiol. 138:741.

Macfarlane, W. V., Pamela R. Pennycuik, N. T. M. Yeates and E. Thrift. 1959. Reproduction in hot environments. Recent progress in the endocrinology of reproduction. Edited by C. W. Lloyd. Academic Press, New York.

McLaren, Anne and Donald Michie. 1956. Studies on the transfer of fertilized mouse eggs to uterine foster-mothers. I. Factors affecting the implantation and survival of native and transferred eggs. J. Exp. Biol. 33:394.

Ulberg, L. C. 1958. The effects of climate on animal performance. The influence of high temperature on reproduction. J. Heredity 49:62.

Yeates, N. T. M. 1956. The effect of high air temperature on pregnancy and birth weight in Merino sheep. Australian J. Agr. Res. 7:435.

UTILIZATION OF SOYBEAN PROTEIN BY BABY PIGS AND BY RATS

J. H. MANER,[1] W. G. POND AND J. K. LOOSLI

Cornell University,[2] Ithaca, New York

THE performance of young pigs fed all-plant protein rations does not approach that of pigs fed rations containing milk protein (Lewis *et al.*, 1955; Sewell, 1953). Lewis *et al.* (1957) reported a proteolytic enzyme insufficiency in the young pig and attributed the poor utilization of soybean protein to this inadequately developed enzyme system. However, other workers (Cunningham and Brisson, 1957; Alsmeyer *et al.*, 1957; Calder *et al.*, 1959) were unable to obtain any improvement in performance when proteolytic enzyme preparations were added to rations containing soybean-protein.

Hays *et al.* (1959) fed a semi-purified diet containing soybean oil meal to pigs 10 days of age and reported a significant improvement in weight gains and feed conversion when 0.05 percent DL-methionine was added to the 20% protein ration.

In the studies reported herein, growth, digestion and nitrogen balance trials were conducted to study: (1) the effects of pepsin, trypsin, and age on utilization of soybean-protein by the young pig, (2) the effect of methionine, lysine and tryptophan additions to an isolated soybean-protein basal diet, and (3) the effects of casein and 3 sources of soybean protein on rat growth.

Experimental Procedure

All experiments were conducted in individual wire-floor metal cages. All pigs within each replicate except those in Experiment 4 were fed equal quantities of feed four times per day at 8 a.m., 12 noon, 4 p.m. and 10 p.m. The level of intake was determined by the animal within each replicate that consumed the least. Pigs in Experiment IV were fed at a daily rate of 6% of their body weight. The rats were offered feed and water *ad libitum*.

Experiment I. Twenty-four newborn pigs were taken at birth without receiving colostrum, injected intraperitoneally with 15 ml. of porcine gamma globulin, and allotted to six treatment groups on the basis of weight and litter. These outcome groups were used in an experiment designed to study the effect of adding pepsin and/or trypsin to an isolated soybean-protein basal diet containing 28% protein. Weight gains and protein digestibility were also compared when casein instead of soybean protein served as the protein source. The six treatments consisted of: (1) basal soybean-protein diet; [3] (2) basal plus 1.0% pepsin; [4] (3) basal plus 0.5% trypsin; [5] (4) basal plus 1.0% pepsin and 0.5% trypsin; (5) basal plus 1.0% pepsin fed in a gelatin capsule; and (6) casein diet. All enzymes were added to the milk diets just prior to feeding. The diets are shown in table 1.

Experiment II. Twenty 3-day-old pigs were allotted to the 4 treatment groups on the basis of litter and weight. In this experiment treatments 3 and 5 of Experiment I were omitted and treatments 1, 2, 4 and 6 were repeated. The diets used were the same as in Experiment I except that 0.55% DL-methionine was added to the soybean-protein basal diet.

Experiment III. Twenty-five 3-day-old pigs were used to study the effect of two added levels of DL-methionine supplementation to a soybean-protein basal diet and again to compare soybean protein and casein. The 5 diets are presented in table 1. All diets contained 28% protein except treatment 5 which was adjusted to 26.5% protein on the basis of previously determined digestion coefficients in an attempt to supply the same quantity of absorbed nitrogen from casein and soybean protein. The basal soybean-protein diet was calculated to contain 0.28% methionine and 0.17% cystine. DL-methionine was added at levels of 0.23 and 0.45% in diets 2 and 3, respectively, so as to supply diets containing 0.45, 0.68 and 0.90% methionine-cystine.

[1] Present address: The Rockefeller Foundation, Apartado Aereo 58–13, Bogota, Colombia.

[2] Department of Animal Husbandry.

[3] Dracket C–1 Assay Protein obtained from Archer Daniels-Midland Company, Cincinnati, Ohio used in all pig studies. For description and amino acid composition see Altschul, Processed Plant Protein Foodstuffs, Acad. Press, 1958.

[4] Pepsin (1–10,000) obtained from Nutritional Biochemicals Corp., Cleveland, Ohio.

[5] Trypsin (4 x U.S.P. Pancreatin) obtained from Nutritional Biochemicals Corp., Cleveland, Ohio.

TABLE 1. COMPOSITION[a] OF DIETS USED IN EXPERIMENTS I, II AND III

Experiment no.	I		II[b]	III		
					Casein	
Diet	Soybean-protein basal	Casein	Soybean-protein basal	Soybean-protein basal	28% protein	26.5% protein
	gm.	gm.	gm.	gm.	gm.	gm.
Isolated soybean-protein[c]	44.26	....	43.37	45.60	.....	.....
Crude casein	.....	44.26	.....	.....	43.72	41.38
Dextrose (Cerelose)	44.14	44.14	44.29	42.80	44.68	47.02
Lard	33.03	33.03	33.03	33.03	33.03	33.03
Soya lecithin	2.00	2.00	2.00	2.00	2.00	2.00
Minerals[d]	10.69	10.69	10.69	10.69	10.69	10.69
Vitamins[e]	+	+	+	+	+	+

[a] Composition expressed as gm. per liter of finished milk.
[b] The casein diet used in Experiment II was the same as in Experiment I.
[c] Drackett C-1 Assay Protein was the source of soybean protein in all experiments.
[d] Minerals added (gm. per l. of finished milk), Experiments I and II: KOH, 0.959; NaOH, 0.928; $CaCl_2$, 1.565; $CaCO_3$, 0.140; HCl, 0.101; MgO, 0.298; KH_2PO_4, 2.873; citric acid, 1.998; $FeSO_4 \cdot 7H_2O$, 0.050; $CuSO_4 \cdot 5H_2O$, 0.004; $CoCl_2 \cdot 6H_2O$, 0.0014; $MnSO_4 \cdot H_2O$, 0.0034; $ZnSO_4 \cdot 7H_2O$, 0.0031; KI, 0.0003 and $Ca(OH)_2$, 1.0. In Experiment III the same minerals were added except that $FeSO_4 \cdot 7H_2O$, $CuSO_4 \cdot 5H_2O$, $CoCl_2 \cdot 6H_2O$ and KI were doubled, $MnSO_4 \cdot H_2O$ was increased 5x and $ZnSO_4 \cdot 7H_2O$ was increased 10x.
[e] Vitamins added (units per l. of finished milk), Experiments I and II: thiamine, 0.65 mg.; riboflavin, 0.65 mg.; niacin, 2.50 mg.; inositol, 26.00 mg.; choline chloride, 260.00 mg.; para amino benzoic acid, 2.60 mg.; folic acid, 0.052 mg.; pyridoxine, 0.65 mg.; calcium pantothenate, 1.30 mg.; vitamin E, 1.00 mg.; menadione, 0.28 mg.; ascorbic acid, 10.00 mg.; vitamin B_{12}, 10.00 mcg.; vitamin A, 2000 I.U. and vitamin D, 200 I.U. Amount of each vitamin doubled in Experiment III.

Thus, the sulfur amino acids equalled 1.6, 2.4 and 3.2% of the protein.

During the third week of the trial digestibility and nitrogen retention data were obtained on all animals in treatment groups 1, 3 and 4.

Experiment IV. Eight 10-week-old, male, littermate pigs were divided into two groups to compare weight gains, digestibility and nitrogen retention produced by a casein and an isolated soybean-protein diet. The composition of the diets is shown in table 2. Both diets contained 12% protein and 5% fat (corn oil). The animals were fed at a daily rate of 6% of their body weight at the beginning of the collection period, which lasted 7 days and followed a 7-day preliminary period.

TABLE 2. COMPOSITION OF DIETS USED IN EXPERIMENT IV

Treatments	Soybean-protein	Casein
	%	%
Isolated soybean protein	14.6	....
Crude casein	....	14.0
Dextrose (Cerelose)	55.4	56.0
Dextrin	15.0	15.0
Corn oil	5.0	5.0
Cellulose (Solka-Floc)	4.0	4.0
Minerals[a]	6.0	6.0
Vitamins[b]	+	+

[a] Minerals added per kg. of diet: $CaHPO_4 \cdot 2H_2O$, 13.22 gm.; $CaCO_3$, 10.35 gm.; KH_2PO_4, 14.3 gm.; NaCl, 5.07 gm.; $CuSO_4 \cdot 5H_2O$, 0.05 gm.; $FeSO_4 \cdot 7H_2O$, 0.55 gm.; KI, 0.33 mg.; $MnSO_4 \cdot H_2O$, 0.15 gm.; $ZnSO_4 \cdot 7H_2O$, 0.29 gm.; and MgO, 0.68 gm.
[b] Vitamins added per kg. of diet: thiamine, 2.64 mg.; riboflavin, 6.61 mg.; niacin, 44 mg.; Ca Pantothenate, 26 mg.; pyridoxine, 2.20 mg.; cobalamine (B_{12}), 10.0 μg.; folic acid, 2.0 mg.; menadione, 4.41 mg.; inositol, 0.91 gm.; para amino benzoic acid, 0.20 gm.; choline, 2.2 gm.; vitamin E acetate 0.75 gm.; vitamin A, 10,573 I.U. and vitamin D, 1,322 I.U.

Experiment V. Forty weanling rats were used to compare the growth and feed efficiency produced by casein and three different soybean-protein sources. The soybean proteins used were soybean oil meal (44%), Promine[6] and Drackett C-1 assay protein. The composition of the diets appears in table 3. All diets contained 10% protein and 5% fat (corn oil).

Experiment VI. Seventy-two weanling rats were allotted into 9 groups of 8 animals each on the basis of sex and weight. A randomized block design was used in a 2^3 factorial experiment which consisted of an isolated soybean-protein basal diet with all possible combinations of three supplemental amino acids comprising eight treatments and a ninth treatment utilizing casein as the protein source. The composition of the basal diets is presented in table 3. The amino acid supplements were DL-methionine, L-lysine and DL-tryptophan and were added at a rate of 0.4, 0.1 and 0.05% of the diet, respectively. All diets contained 12% protein and 5% fat (corn oil) and the basal soybean-protein diet was calculated to contain 0.20% methionine-cystine, 0.81% lysine and 0.12% tryptophan.

[6] Isolated soybean protein obtained from Central Soya Company, Inc., Fort Wayne, Indiana; formerly sold by The Glidden Company, Chicago, Illinois. For description and amino acid composition see Altschul, Processed Plant Protein Foodstuffs, Acad. Press, 1958.

TABLE 3. COMPOSITION OF DIETS USED IN EXPERIMENTS V AND VI

Experiment	V				VI	
	Casein	Soybean oil meal	Promine	Drackett C–1 assay protein	Casein	Drackett C–1 assay protein
	%	%	%	%	%	%
Casein	11.65	.....	.....	.....	14.00	.....
Soybean oil meal (44%)	.....	21.43	.....	.....	.....	.....
Promine	.....	.....	11.56	.....	.....	.....
Drackett C–1 assay protein	.....	.....	.....	12.15	.....	14.60
Corn oil	5.00	5.00	5.00	5.00	5.00	5.00
Dextrose (Cerelose)	72.84	64.31	72.93	72.34	70.49	69.89
Cellulose (Solka-Floc)	1.25	.....	1.25	1.25	1.25	1.25
Vitamin premix[a]	5.00	5.00	5.00	5.00	5.00	5.00
Minerals[b]	4.26	4.26	4.26	4.26	4.26	4.26

[a] Vitamins added (in cerelose) per kg. of diet: thiamine, 2.5 mg.; riboflavin, 5.0 mg.; pyridoxine, 2.4 mg.; niacin, 30 mg.; Ca pantothenate, 16 mg.; choline chloride, 1.5 gm.; B_{12}, 10 μg.; vitamin A, 4200 I.U.; vitamin D, 135 I.U.; vitamin E acetate, 120 mg.; menadione, 0.2 mg.

[b] Minerals added per kg. of diet: $CaHPO_4 \cdot 2H_2O$, 30 gm.; KH_2PO_4, 7 gm.; $CaCO_3$, 3 gm.; NaCl, 1.5 gm.; MgO, 0.4 gm.; $MnSO_4 \cdot H_2O$, 0.3 gm.; $FeSO_4 \cdot 7H_2O$, 0.25 gm.; $CuSO_4 \cdot 5H_2O$, 0.30 gm.; $ZnSO_4 \cdot 7H_2O$, 0.10 gm.; $Na_2SeO_3 \cdot 5H_2O$, 0.40 mg.

TABLE 4. RESULTS OF EXPERIMENT I. EFFECT OF SUPPLEMENTAL PROTEOLYTIC ENZYMES ON GROWTH AND NUTRIENT DIGESTIBILITY IN BABY PIGS FED SOYBEAN PROTEIN

Treatment[a]	Isolated soybean-protein					
	Basal	Pepsin	Trypsin	Pepsin+ Trypsin	Pepsin (capsule)	Casein
Av. initial wt., lb.	2.75	2.80	2.60	2.73	3.00	2.83
Av. daily gain, lb.	0.12	0.12	0.11	0.12	0.10	0.15
Air dry feed/lb. gain, lb.	1.21	1.21	1.30	1.24	1.46	0.95
Dry matter digestibility, %	88.5	90.1	89.0	89.3	88.4	94.9
Protein digestibility, %	89.8	90.9	90.6	90.3	89.0	96.6

[a] Four individually housed pigs per treatment; experimental period 22 days.

Results

Experiment I. The average weight gain, feed efficiency and digestibility data for the six treatment groups are shown in table 4. Pepsin and/or trypsin additions to the soybean-protein diet had no significant effect on growth or feed conversion for the 22-day experimental period. However, pigs receiving the casein diet grew 30% faster ($P<0.05$) on 26% less feed per unit of gain when compared to an average of all the soybean-protein groups. The improvement in feed conversion was not statistically significant ($P<0.05$).

Pepsin and/or trypsin had no measurable effect on protein digestibility during the 22-day trial. The digestion coefficient of the casein was 96.6% as compared to an average of 90.1% for soybean protein.

Experiment II. The average performance and digestibility data for this experiment are presented in table 5. Again, as demonstrated in Experiment I, there were no significant differences in weight gains or feed conversion due to the addition of pepsin or pepsin and trypsin. Casein was again superior to soybean protein in stimulating weight gains and feed conversion in pigs 3 to 27 days of age ($P<0.01$) by producing 33% greater gains on 25% less feed per unit of gain.

TABLE 5. RESULTS OF EXPERIMENT II. EFFECT OF SUPPLEMENTAL PROTEOLYTIC ENZYMES ON GROWTH AND NUTRIENT DIGESTIBILITY IN BABY PIGS FED SOYBEAN PROTEIN

Treatment[a]	Isolated soybean-protein			
	Basal	Pepsin	Pepsin+ trypsin	Casein
Av. initial wt., lb.	3.30	3.32	3.44	3.34
Av. daily gain, lb.	0.17	0.17	0.18	0.23
Air dry feed/lb. gain, lb.	1.36	1.28	1.29	0.99
Dry matter digestibility, %	94.5	92.3	93.1	96.8
Protein digestibility, %	93.9	91.4	92.6	97.3

[a] Five individually housed pigs per treatment; experimental period 24 days.

TABLE 6. RESULTS OF EXPERIMENT III. EFFECT OF SUPPLEMENTAL METHIONINE ON GROWTH, NUTRIENT DIGESTIBILITY AND NITROGEN RETENTION IN BABY PIGS FED SOYBEAN PROTEIN

Treatment[a]	Isolated soybean-protein basal			Casein	
	Basal	+0.23% methionine	+0.45% methionine	28% protein	26.5% protein
Av. initial wt., lb.	3.34	3.30	3.32	3.34	3.33
Av. daily gain, lb.	0.14	0.17	0.16	0.22	0.23
Air dry feed/lb. gain, lb.	1.52	1.55	1.35	1.00	0.94
Days on collection	7	....	7	7	....
Dry matter digestibility, %	93.0	....	92.3	97.3	....
Ether extract digestibility, %	95.8	....	95.7	97.6	....
Protein digestibility, %	91.7	....	89.7	98.2	....
Nitrogen retained, gm.	21.0	....	22.8	26.5	....
Digested nitrogen retained, %	58.0	....	64.5	70.4	....

[a] Five individually housed pigs per treatment; experimental period 21 days.

Experiment III. The weight gains, feed efficiency, digestibility and nitrogen retention data are presented in table 6. Supplemental DL-methionine improved the average daily gains during the 21-day experiment from 0.14 lb. on the 28% protein soybean-protein basal to 0.17 lb. on the 0.23% level of supplemental methionine and 0.16 lb. on the 0.45% level. However, with crude casein the gains were 0.22 lb. per day on the 28% protein diet and 0.23 lb. per day on the 26.5% protein diet. The difference between casein and soybean protein was statistically significant ($P<0.01$), but the improvement due to methionine was not significant.

Feed efficiency data followed the same pattern as the growth data. Methionine supplementation at the 0.45% level tended to reduce the grams of feed required to produce a gram of gain but no improvement occurred at the 0.23% level. Feed efficiency was 32.6% higher on casein than on soybean protein ($P<0.01$).

At 3 weeks of age the pigs digested 93.0 and 92.3% of the dry matter of the unsupplemented and supplemented soybean-protein diets, respectively as compared to 97.3% of the casein diet, 95.8 and 95.7% of the ether extract as compared to 97.6% and 91.7 and 89.7% of the protein as compared to 98.2%. As would be expected, methionine supplementation had no measurable effect on the digestibility of the various ration components. However, significantly ($P<0.01$) higher digestion coefficients were observed for all three components of the casein diet. The percent of digested nitrogen retained was greater for the casein diet, 70.4% for the casein as compared to 58.0% for the soybean-protein basal and 64.5% for the soybean protein supplemented with 0.45% DL-methionine. Methionine added to the basal diet increased the nitrogen retention over the basal by 11.2%, but substituting casein for soybean protein increased nitrogen retention by 21%. The differences between casein and soybean protein and between the methionine supplemented and unsupplemented diets were statistically significant ($P<0.05$).

Experiment IV. As shown in table 7, the 10-week-old pigs receiving the 12% protein, casein diet gained an average of 9.57 lb. on 2.10 lb. of feed per lb. of gain as compared to 6.52 lb. on 2.81 lb. of feed per lb. of gain for pigs receiving the 12% protein, isolated soybean-protein diet, with differences both in gain and feed conversion being statistically significant ($P<0.05$).

There were no significant differences in the digestion coefficients of the dry matter, ether extract, or protein between the two protein diets at 10-weeks of age. However, although the same amounts of nitrogen were absorbed by both groups, the percentage of absorbed nitrogen retained was 35% greater for the

TABLE 7. RESULTS OF EXPERIMENT IV. NUTRIENT DIGESTIBILITY AND NITROGEN RETENTION IN TEN-WEEK-OLD PIGS FED SOYBEAN PROTEIN OR CASEIN

Treatment[a]	Isolated soybean-protein	Crude casein
Av. initial wt., lb.	44.03	49.58
Av. daily gain, lb.	0.93	1.37
Feed/lb. gain, lb.	2.81	2.10
Dry matter digestibility, %	92.8	92.9
Ether extract digestibility, %	94.6	96.0
Apparent protein digestibility, %	92.8	93.1
Nitrogen retained, gm.	85.4	123.1
Digested nitrogen retained, %	57.9	78.2

[a] Four individually housed pigs per treatment; experimental period 7 days.

TABLE 8. RESULTS OF EXPERIMENT V. EFFECT OF SOURCE OF SOYBEAN PROTEIN ON PERFOMANCE OF WEANLING RATS

Treatment[a]	Casein	Soybean oil meal	Promine	Drackett C-1 assay protein
Av. initial wt., gm.	40.2	39.5	40.1	41.0
Av. daily gain, gm.	2.5	2.4	1.4	1.2
Av. daily feed intake, gm.	11.9	13.1	11.6	11.2
Feed/gm. gain, gm.	5.10	5.58	9.06	9.50

[a] Ten individually caged rats per treatment; experimental period 28 days.

casein group than for the soybean-protein group. This difference was statistically significant ($P<0.01$).

Experiment V. The results are summarized in table 8. Casein and soybean oil meal fed to rats promoted comparable gains and feed conversions which were significantly ($P<0.01$) greater than those produced by either Promine or Drackett C-1 assay protein. Promine stimulated slightly greater average gains than Drackett, but this difference was not significant.

Experiment VI. The results are summarized in table 9. The addition of 0.4% DL-methionine to the basal soybean-protein ration fed to rats had the greatest effect on growth and feed efficiency, regardless of the amino acid combination in which it was contained. The addition of methionine alone or in combination with supplemental lysine and/or tryptophan significantly ($P<0.01$) improved growth and feed efficiency. Orthogonal comparisons made on the data revealed that 90% of the variation was due to the methionine component of variance. Although the differences were not statistically significant, the addition of either 0.1% L-lysine or 0.05% DL-tryptophan or a combination of both depressed growth rate and feed efficiency when compared to the soybean-protein basal; however, this depression did not occur when 0.40% methionine was added to the diets. The growth and feed efficiency produced by the casein diet were significantly greater than obtained with the soybean-protein basal diet. However, when supplemented with 0.40% DL-methionine this diet produced gain and feed efficiency not statistically different from the casein diet.

Discussion

The results presented in Experiments I and II do not support the work reported by Lewis *et al.* (1955, 1957) who attributed the poor utilization of soybean protein by the young pig to an inadequately developed proteolytic enzyme system. In contrast, these data add support to the evidence presented by Cunningham and Brisson (1957), Alsmeyer *et al.* (1957), Hudman and Peo (1957) and Calder *et al.* (1959) that the addition of proteolytic enzymes to either liquid or solid diets containing soybean protein has no measurable effect on growth or protein digestibility. These trials indicate that other factors besides proteolytic enzymes apparently are responsible for the failure of baby pigs to make maximal use of soybean protein.

The improvement in growth, feed efficiency and nitrogen retention which resulted from the addition of 0.45% DL-methionine to the basal diet showed that a methionine-cystine deficiency existed in the soybean-protein diet and that this was partially responsible for the poor utilization of nitrogen. However, even the level in the supplemented diet (0.90%), which would appear to be sufficient to meet the needs of the newborn pig, failed to produce nitrogen retention equal to that obtained with casein. Poor amino acid utilization due to a deficiency, unavailability, or excess of some amino acid or acids other than methionine-

TABLE 9. RESULTS OF EXPERIMENT VI. EFFECT OF SUPPLEMENTAL AMINO ACIDS ON PERFORMANCE OF WEANLING RATS FED SOYBEAN PROTEIN

Treatment[a]	Casein	Isolated soybean-protein						
		Basal	M[b]	L[b]	T[b]	M+L	M+T	L+T	M+L+T
Av. initial wt., gm.	39.1	39.4	38.8	39.3	38.9	39.1	38.0	40.3	40.3
Av. daily gain, gm.	3.0	1.9	3.2	1.7[c]	1.7[c]	2.9	3.1	1.7	3.2
Av. daily feed, gm.	10.8	10.4	10.8	9.9	9.7	10.4	10.8	9.9	10.8
Feed/gm. gain, gm.	3.73	5.70	3.55	6.04	5.96	3.79	3.61	5.94	3.67

[a] Eight individually caged rats per treatment; experimental period 21 days.
[b] The amino acids were added at the following rates: M(DL-methionine), 0.40%; L(L-lysine), 0.10%; T(DL-tryptophan), 0.05%.
[c] One animal died during the course of the experiment; average based on 7 rats.

cystine or unavailability of the methionine-cystine present in soybean protein after isolation are suggested as possible factors responsible for the poor response obtained with this protein. Also, the possibility exists that the methionine-cystine requirement of the baby pig may be greater than 0.90% of the diet or 3.2% of the protein, as reported for weanling pigs by Curtin *et al.* (1952). A higher requirement might also be indicated by the results reported by Hays *et al.* (1959) who obtained an increase in growth (11.0 vs. 17.8 lb.) when 0.05% DL-methionine was added to a basal diet containing soybean oil meal and calculated on the basis of average values to contain 0.29% methionine and 0.33% cystine, to raise the sulfur amino acid level to 3.35% of the protein.

A direct comparison of the results obtained on pigs 3 weeks and 10 weeks of age cannot be made because of the differences in composition and consistency of the diets used. However, a comparison of the differences within age groups can be considered. The differences in digestibility of dry matter, ether extract, and protein that occurred between isolated soybean protein and casein at 3 weeks of age did not occur at 10 weeks of age. However, the poor utilization of soybean-protein nitrogen after absorption was observed at both 3 and 10 weeks. Age is, therefore, a factor involved in plant protein digestion and utilization as noted by Lloyd *et al.* (1957) and Hays *et al.* (1959).

As observed with young pigs, isolated soybean protein did not support growth or feed conversion in rats equal to that obtained with casein. However, soybean oil meal (44%) produced gains and feed conversion not statistically different from those produced by casein. These observations confirm the detrimental effect of the isolation process on the soybean protein.

When the methionine-cystine deficiency that existed in the soybean-protein diet which was fed to the rats was corrected by adding DL-methionine to meet the quantitative requirements reported, the protein supported weight gains equal to those produced by casein. These results, however, are not in agreement with those obtained with pigs. This difference in response would suggest a difference in the ability of these two species, at the ages considered, to use the soybean protein for growth.

Summary

Studies with young pigs and rats to evaluate the effect of proteolytic enzymes, amino acids and age on utilization of isolated soybean protein are reported.

Pepsin and/or trypsin added to a basal soybean-protein diet had no effect on baby pig growth, feed efficiency, or protein digestibility. DL-methionine added to the same basal diet at levels of 0.23 and 0.45% to provide a total of 0.68 and 0.90% methionine-cystine increased gain and the 0.45% added methionine improved nitrogen retention and feed conversion when compared to the basal. When casein was used as the protein source, gains, feed conversion, digestibility of the various ration components, and nitrogen retention were significantly improved over the basal or methionine-supplemented soybean-protein diets.

The differences in the digestibility of the ration components observed between soybean protein and casein at 3 weeks of age did not occur at 10 weeks of age. Retention of absorbed nitrogen followed the same pattern in both age groups.

When fed to rats, casein and soybean oil meal produced comparable gains and feed conversions which were significantly greater than those produced by either Promine or Drackett C-1 assay protein. DL-methionine supplementation to the soybean-protein basal diet produced gains equal to those obtained with casein in contrast to the results obtained with pigs. L-lysine and/or DL-tryptophan added to this basal diet in the absence of added methionine had no significant effect on growth.

Literature Cited

Alsmeyer, W. L., G. E. Combs, Jr., and H. D. Wallace. 1957. Enzyme supplementation of baby pig rations containing various carbohydrate and proteinaceous feedstuffs. J. Animal Sci. 16:1040.

Calder, A. F. C., G. A. Lodge, and R. Blair. 1959. The early weaning of pigs. V. The inclusion of digestive enzymes and antibiotics in diets for pigs weaned at 6–7 lbs. liveweight. J. Agr. Sci. 53:130.

Cunningham, H. M. and G. J. Brisson. 1957. The effect of proteolytic enzymes on the utilization of animal and plant proteins by newborn pigs and the response to predigested protein. J. Animal Sci. 16:658.

Curtin, L. V., J. K. Loosli, Jean Abraham, H. H. Williams, and L. A. Maynard. 1952. The methionine requirement for growing swine. J. Nutr. 48:499.

Hays, V. W., V. C. Speer, P. A. Hartman and D. V. Catron. 1959. The effect of age and supplemental amino acids on the utilization of milk and soya protein by the young pig. J. Nutr. 69:179.

Hudman, D. B., and E. R. Peo, Jr. 1957. Comparison of early-weaned and sow-raised pigs. Science Progress Report 350. Nebraska Agr. Expt. Sta., Univ. of Nebraska, page 20.

Lewis, C. J., D. V. Catron, C. H. Liu, V. C. Speer and G. C. Ashton. 1955. Enzyme supplementation of baby pig diets. J. Agr. Food Chem. 3:1047.

Lewis, C. J., P. A. Hartman, C. H. Liu, R. O. Baker and D. V. Catron. 1957. Digestive enzymes of the baby pig. Pepsin and Trypsin. J. Agr. Food Chem. 5:687.

Lloyd, L. E., E. W. Crampton, and V. C. MacKay. 1957. The digestibility of ration nutrients by three vs. seven-week old pigs. J. Animal Sci. 16:383.

Sewell, R. F. 1953. The threonine and protein requirements of suckling pigs. Ph.D. thesis. Cornell University.

ESTROUS CYCLE REGULATION IN THE BOVINE[1]

W. HANSEL, P. V. MALVEN AND D. L. BLACK[2,3]

Cornell University, Ithaca, New York

IN recent years an increasing number of investigators have become interested in the possibility of artificial regulation of estrous cycles in various classes of livestock. A development of this sort, enabling groups of beef cattle to be bred on a single day without loss of normal fertility, would probably lead to the widespread application of artificial insemination. Interest in this subject declined after earlier studies showed that although the cycle could be effectively regulated in cattle by progesterone injections, the fertility of cattle bred at the first estrus following such treatments was reduced (Trimberger and Hansel, 1955; Nellor and Cole, 1956). The recent development of new methods for altering the bovine estrous cycle (Hansel and Wagner, 1960) as well as the development of new progestational compounds that are orally effective in monogastric animals (Nellor, 1960) have served to revive interest in the subject.

Experimental Procedure

The experiments to be reported consisted of three separate trials involving 77 grade Hereford cattle.

In Trial I, conducted in the spring of 1959, 27 two-year-old heifers were allotted to three different treatment groups, each treatment being designed to bring the heifers in that particular group into estrus during a "target" period of approximately 3 days.

All animals were observed three times daily for signs of estrus beginning 30 days prior to the proposed target period. Those which came in estrus 23–30 days prior to the target period were recycled by oxytocin injections, as previously described (Armstrong and Hansel, 1959). Seven daily subcutaneous injections consisting of 100 U.S.P. units of oxytocin[4] each were made beginning on the day after estrus. Those animals which came in estrus 19–22 days prior to the target period were not treated. Animals coming in estrus less than 19 days prior to the target period were given 7 daily subcutaneous injections of 130 U.S.P. units of oxytocin and daily subcutaneous injections of 50 mg. of progesterone in corn oil concurrent with and subsequent to the oxytocin injections. The progesterone injections were discontinued 4 days prior to the target dates. The three groups in this trial thus consisted of (1) five heifers scheduled for breeding after a normal cycle following recycling by oxytocin injections, (2) nine untreated heifers scheduled for breeding after a normal cycle, and (3) thirteen heifers scheduled for breeding at an artificially induced estrus following combined oxytocin and progesterone treatment.

All heifers showing estrus during the desired period in Trial I were artificially inseminated with semen of apparently normal motility, concentration and morphology collected from a single Hereford bull. A minimum of 10 million motile spermatozoa were used for each insemination. Rectal palpations were made on all heifers at 1 day after breeding to determine if ovulation had occurred, and at 60 days after insemination to determine if pregnancy occurred. Calving dates were checked to confirm the earlier pregnancy diagnoses.

Trial II, conducted during the summer of 1960, involved 32 Hereford cows bred after feeding 6-methyl-17-acetoxyprogesterone,[5] a progestational compound which in preliminary feeding experiments with Holstein heifers, had effectively inhibited estrus and ovulation until 3–4 days after its withdrawal. This compound was fed once daily for 20 days in soybean meal. Approximately 4 lb. of soybean meal containing the hormone was fed each animal daily. The animals were placed in a drylot

[1] Supported in part by funds provided by the regional research project, NE-41 entitled "Endocrine Factors Affecting Reproduction and Lactation in Dairy Cattle," a cooperative study by Agricultural Experiment Stations in the Northeast and the Dairy Husbandry Research Branch, ARS, USDA, and in part by the National Association of Artificial Breeders and the New York Artificial Breeders Cooperative. Most of the cattle used were provided by Zenda Farms, Clayton, New York and G. Hadlock, Hammond, New York.

[2] Present address: University of Massachusetts, Amherst, Massachusetts.

[3] The authors gratefully acknowledge the assistance of R. W. Bratton, W. C. Wagner and J. M. Briggs, Cornell University and R. W. Kittle, Manager, Zenda Farms, in carrying out these experiments.

[4] P.O.P. was kindly supplied by M. E. Davenport, Armour Pharmaceutical Laboratories, Kankakee, Illinois.

[5] "Provera", was kindly supplied by R. A. Gessert, The Upjohn Co., Kalamazoo, Michigan.

overnight and the feed placed in a feeder each morning. They were turned out to graze during the day. No attempt was made to feed any of the cows individually. All cows were nursing calves.

During the first 10 days of the feeding period each 4 lb. of soybean meal contained 968 mg. of 6-methyl-17-acetoxyprogesterone; during the second 10-day period the level was reduced to 500 mg. per 4 lb. of soybean meal. Since the average weight of the cows as indicated by heart girth measurements was 1000 lb., these levels were equivalent to approximately 0.968 and 0.500 mg. of hormone per lb. of body weight per day, respectively.

The animals were checked for estrus twice daily and all animals were artificially inseminated 3–5 days after withdrawal of the progestational compound whether or not they came in estrus. Ten of the 32 cows were inseminated on two consecutive days with 20 million motile sperm; the remaining 22 cows were inseminated once or, in some cases, on two consecutive days with 3.6 million motile spermatozoa. The latter figure is lower than the number necessary for maximal fertility in dairy cattle, but is nevertheless high enough that one might expect acceptable conception rates (Bratton *et al.*, 1954).

In addition, half of the cows, selected at random, were injected subcutaneously with 0.5 mg. of estradiol at the time of insemination.

Pregnancies were checked by rectal palpations at 50–60 days after insemination.

In Trial III, 18 cows were fed daily for 20 days 187 mg. of 17α-ethynyl-17-hydroxyestr-5(10)-en-3-one (containing 1.5% 3-methyl ether of ethinyl estradiol) [6] in an amount of soybean meal equivalent to 5.5 lb. per cow per day. The cattle were handled as in Trial II. None of these animals was bred after the treatment period.

[6] "Enovid" was kindly supplied by G. E. Short, G. D. Searle and Co., Chicago, Illinois.

Results

Nine of the 27 heifers in Trial I showed estrus 23–30 days prior to the proposed insemination period, and these were injected with oxytocin as previously described. Seven of the nine responded to the injections by returning to estrus in 8–10 days after the previous estrus. The remaining two animals returned to estrus in 14 and 17 days, respectively.

The precocious estrous periods in five of these nine heifers and the first observed naturally occurring estrous period in seven additional heifers all occurred 19–22 days before the target period, and these animals were allowed to cycle without any further treatment. The mean length of these cycles was 20.8±1.5 days for those heifers which had previously been recycled with oxytocin and 20.0±2.0 days for those which had not received any previous treatment.

The four remaining heifers which had been recycled with oxytocin and the nine remaining untreated heifers came in estrus at varying times 10–19 days before the target period. These 13 heifers were all treated with both oxytocin and progesterone as previously described (Group 3). Estrus occurred on the average 6.7±1.4 days after cessation of the progesterone injections in this group.

The two remaining heifers of the 27 showed no estrous activity during the 30 days prior to the target period, but came in estrus at about the desired time without any treatment.

The number of animals coming in estrus during the 3-day target period, 2 days before the desired period, and 3 days following the desired period is shown in table 1.

Table 1 shows that 26 of the 27 heifers came in estrus during an 8-day period, and that in 8 of the 26 estrus occurred during the 3-day target period. The failure to obtain a higher percentage of animals in estrus during the target period was due primarily to the 13 oxytocin-progesterone treated heifers. Most of these heifers came in estrus

TABLE 1. THE FREQUENCY OF OCCURRENCE OF ESTRUS IN HEREFORD HEIFERS IN TRIAL I DURING, PRIOR TO, AND FOLLOWING THE TARGET PERIOD

Treatment group	No. of heifers	Days[a]							
		−2	−1	1	2	3	4	5	6
No treatment	9	2	..	3	..	2	1	1	..
Recycled by oxytocin	4	..	2	1	..	..	..	1	..
Oxytocin plus progesterone	13	..	..	1	..	1	1	5	5
Total		2	2	5	..	3	2	7	5

[a] Days 1, 2 and 3 constitute the target period.

6–8 days following the last progesterone injection, rather than 3–5 days after the last injection as had been anticipated. This resulted in 14 animals being in estrus on the 3 days following the target period.

Thirteen (50%) of the heifers conceived at the first insemination. These included four of thirteen oxytocin-progesterone treated heifers, seven of nine untreated heifers, and two of four heifers bred at an estrus following a normal cycle which was initiated after recycling by oxytocin. One of the oxytocin treated heifers that came in estrus 19-22 days prior to the desired date also returned to estrus a second time 8 days prior to the target period. An attempt was made to recycle her a second time with oxytocin, but she did not return to heat for a prolonged period and consequently was not bred during the experiment. The 13 animals which conceived during the 8-day insemination period calved in a 16-day period.

The results of Trial II are shown in table 2, from which it may be seen that feeding 6-methyl-17-acetoxyprogestrone prevented all 32 cows from coming in estrus during the 20-day feeding period.

Estrus occurred in 16 of the 32 cows following the withdrawal of the hormone and these cows were inseminated on the third and fourth days after the end of the feeding period. Ovulation occurred in 15 of these 16 cows.

The remaining 16 cows were inseminated on the 5th day, even though ovulation had already occurred in eight of them at the time of insemination. Subseqently, five additional cows ovulated without showing estrus.

Eight of the 32 cows (25%) conceived to the first service after the hormone treatment. Three cows that did not come in estrus conceived, and two of these were inseminated after they had ovulated. The estradiol injections given at the time of insemination did not appear to affect fertility, since equal numbers of animals conceived in the injected and non-injected groups.

Eleven of the 32 cows returned to estrus within 25 days after first insemination. These cows were artificially inseminated a second time and seven (63.7%) conceived to this service.

In Trial III the daily oral administration of 187 mg. of 17α-ethynyl-17-hydroxy-estr-5(10)-en-3-one (containing 1.5% 3-methyl ether of ethinyl estradiol) per animal was not effective in preventing estrus. Eleven of the 18 cows came in estrus prior to the 20th day of the feeding period. One cow came in estrus 2 days and another 5 days after the end of the 20-day feeding period.

Discussion

Failure to attain effective synchronization of the estrous cycles in the 27 heifers in Trial I was primarily due to the fact that 11 of the 13 oxytocin-progesterone-treated heifers came in estrus during the 3 days subsequent to the target period. Actually, the results obtained might have been anticipated since Ulberg's (1955) data showed that a rather large proportion of progesterone-treated beef cattle did not return to estrus until the sixth day or later after cessation of the injections, in contrast to the usual 3–5 days reported for dairy cattle.

Although the numbers of animals involved are small, it is worth noting that the conception rate in the progesterone treated heifers (31%) was significantly ($P<0.02$) lower than in the untreated heifers in Trial I, a result which is in agreement with previous reports. This general approach to the problem of estrous cycle regulation seems worthy of further investigation.

The results of Trial II showed that feeding 6-methyl-17-acetoxyprogesterone inhibits estrus and ovulation in the ruminant during the period of its administration as it has been shown to do in monogastric animals such as the mouse (Dziuk, 1960) and the pig (Nellor, 1960). Although 28 of the 32 cows ovulated on the third and fourth days following with-

TABLE 2. THE EFFECTS OF FEEDING AN ORALLY EFFECTIVE PROGESTATIONAL COMPOUND TO CATTLE FOR 20 DAYS

Hormone fed	No. of animals	No. in estrus during treatment	No. in estrus 3–4 days after treatment	No. ovulating after treatment	No. conceiving to post-treatment service	Percent conceiving to post-treatment service
6-methyl-17-acetoxy-progesterone	32	0	16	28	8	25

drawal of the hormone, only 16 came into estrus. This high incidence of ovulations without estrus may have been due to the presence of either too much or too little progesterone following the hormone treatment. High levels of progesterone clearly inhibit the manifestations of estrus in the ruminant. On the other hand, Melampy *et al.* (1957) have presented data which illustrate that small amounts of progesterone facilitate the estrus-inducing effect of estradiol in ovariectomized cattle.

The fertility (25%) of the cows bred at the first estrus after feeding the progestational compound in Trial II also appears to be lower than normal. Although the hormone treatment may have contributed to this low fertility, one other factor may also have been involved. Eight of the 32 cows had ovulated prior to the time they were inseminated, and the conception rate is known to be lowered in dairy cattle bred after ovulation. However, two of the eight cows inseminated after ovulation did conceive, and this factor was probably not entirely responsible for the low fertility obtained.

The reduced fertility of cattle bred at the first estrus following progesterone treatments may be due to either too high or too low a level of progesterone at the time of estrus. The corpora lutea in the progesterone treated animals may have regressed to the point where little or no endogenous progesterone was available after withdrawal of the exogenous source. Alternatively, residual levels of the exogenous progesterone might have been high enough to result in a relative excess of the hormone at the time of ovulation.

Both estrogen and progesterone have been shown to affect the rate of passage of ova from the oviduct into the uterus. The recent findings of Black and Asdell (1959) and Edgar and Asdell (1960), showing that the tubo-uterine junction in the rabbit and in the ewe has a "valve-like" action which controls the entry of ova into the uterus, may be particularly pertinent. In both species it appears that the tubo-uterine junction normally prevents the passage of fluid into the uterus until about 72 hours post-estrus, or post-coitum in the case of the rabbit. A similar mechanism appears to exist in the cow (unpublished, Black, D. L., 1961). Estrogens induce edema and flexure of the wall of the tubo-uterine junction and thus prolong the period during which the valve remains closed. As the level of the progesterone increases, the edema subsides allowing the passage of fluid and ova into the uterus.

Edgar and Asdell (1960) also noted that the tubo-uterine block was inadequate in three of five ewes in which estrus and ovulation were induced by progesterone and gonadotrophin injections during the non-breeding season, suggesting that in these ewes the ova would pass into the uterus at an earlier than normal time. This factor may account, in part, for the lowered fertility reported in ewes bred after the induction of estrus and ovulation by these hormones. Rowson (1951) also reported that bovine ova travel down the oviducts at a greatly increased rate in the presence of progesterone.

Edgar and Asdell (1960) further reported that the injection of stilbestrol on the day of estrus resulted in closure of the tubo-uterine valve in three ewes in which ovulation was induced by progesterone plus gonadotrophin injections. It was for this reason that half of the cows in Trial II were injected with estradiol at the time of insemination. The fertility was not improved in the estrogen-treated animals. This result may indicate that the estrogen dosage (0.5 mg.) was too small to be effective, or that a relative estrogen deficiency of sufficient magnitude to hasten the rate of passage of ova into the uterus did not exist in these cows.

The results of Trial III showed that the oral administration of 187 mg. of 17α-ethynyl-17-hydroxy-estr-5(10)-en-3-one, did not inhibit estrus, but higher levels of this compound might well be effective. Anderson and Melampy (1959) reported that a level of 4 mg. per 100 lb. of body weight inhibited estrus until 2–5 days after the end of treatment in seven of nine gilts. If this compound can be successfully used to synchronize estrous cycles, its slight estrogenic activity may be beneficial in maintaining normal fertility in animals bred at a controlled estrus.

Summary

Three methods of regulating the estrous cycle in Hereford cattle were studied in three separate trials. In Trial I an attempt was made to bring 27 Hereford heifers into estrus during a target period of 3 days by altering the naturally occurring cycles, where necessary, by recycling by means of oxytocin injections or by a combined oxytocin and progesterone treatment. Twenty-six of the 27 heifers were brought into estrus and artifically inseminated within an 8-day period. The

major cause of this dispersion was the relatively long interval (6–8 days) between the cessation of treatment and estrus in the oxytocin-progesterone treated group, which resulted in 14 animals being in estrus on the 3 days following the target period. Fifty percent of the 26 heifers conceived to the first service.

In Trial II a progestational compound, 6-methyl-17-acetoxyprogesterone, was fed in soybean meal to 32 Hereford cows for 20 days. None of these cows came in estrus during the feeding period. Half (16) of the cows came in estrus and were inseminated 3–4 days after cessation of the treatment. An additional 13 cows ovulated without showing estrus. All cows were inseminated, and 25% conceived to the first service. Some of the cows which had "silent" ovulations were inseminated after they had ovulated. Half of the cows in this trial were injected with estradiol at the time of insemination, but the conception rate was not improved by this treatment.

In Trial III the oral administration of 17α-ethynyl-17-hydroxy-estr-5(10)-en-3-one in soybean meal did not prove effective in inhibiting estrus and ovulation.

Literature Cited

Anderson, L. L. and R. M. Melampy. 1959. The effect of norethynodrel and ethynylestradiol 3-methyl ether on reproduction in the gilt. J. Animal Sci. 18:1550 (Abstr.).

Armstrong, D. T. and W. Hansel. 1959. Alteration of the bovine estrous cycle with oxytocin. J. Dairy Sci. 42:533.

Black, D. L. and S. A. Asdell. 1959. Mechanism controlling entry of ova into the rabbit uterus. Am. J. Physiol. 197:1275.

Bratton, R. W., R. H. Foote and C. R. Henderson. 1954. The relationship between fertility and the number of spermatozoa inseminated. J. Dairy Sci. 37:1353.

Dziuk, P. J. 1960. Inhibition and synchronization of mating in the mouse by oral administration of progestins. Endocr. 66:898.

Edgar, D. G. and S. A. Asdell. 1960. The valve-like action of the utero-tubal junction of the ewe. J. Endocr. 21:315.

Hansel, W. and W. C. Wagner. 1960. Luteal inhibition in the bovine as a result of oxytocin injections, uterine dilatation and intrauterine infusions of seminal and preputial fluids. J. Dairy Sci. 43:796.

Melampy, R. M., M. A. Emmerson, J. M. Rakes, L. J. Hanka and P. G. Eness. 1957. The effect of progesterone on the estrous response of estrogen-conditioned ovariectomized cows. J. Animal Sci. 16:967.

Nellor, J. E. 1960. Control of estrus and ovulation in gilts by orally effective progestational compounds. J. Animal Sci. 19:412.

Nellor, J. E. and H. H. Cole. 1956. The hormonal control of estrus and ovulation in the beef heifer. J. Animal Sci. 15:650.

Rowson, L. E. 1951. Methods of inducing multiple ovulation in cattle. J. Endocr. 7:260.

Trimberger, G. W. and W. Hansel. 1955. Conception rate and ovarian function following estrus control by progesterone injections in dairy cattle. J. Animal Sci. 14:224.

Ulberg, L. C. 1955. Synchronization of estrous cycles. Mich. State Univ. Cent. Sym. Report Reproduction and Infertility. p. 184.

EFFECT OF INBREEDING ON PERFORMANCE TRAITS OF BEEF CATTLE [1, 2]

L. A. SWIGER, K. E. GREGORY, ROBERT M. KOCH AND V. A. ARTHAUD [3]

United States Department of Agriculture and University of Nebraska, Lincoln

MOST evidence indicates that inbreeding adversely affects the growth and vitality of animals. Only limited information is available on the magnitude of inbreeding effects on production traits of beef cattle. Estimates of inbreeding effects are needed to adjust records of individual animals in order to increase the accuracy of the selection of breeding animals and to facilitate the analysis of data. Estimates of the effects of inbreeding on production traits would be useful for other purposes. The rate of decline in performance associated with inbreeding should reflect the importance of non-additive gentic variation and thus give some indication of the heterosis that may be expected in these traits. Also, the expected decline in production resulting from inbreeding, particularly as it affects the cost of producing breeding stock, should govern to some extent the use of inbreeding by the industry as a tool for improving cattle. For example, if performance is reduced drastically by inbreeding, the cost of developing highly inbred lines may virtually prohibit their use by breeders. In this study the effects of inbreeding of the calf and inbreeding of the dam were evaluated for birth weight, pre-weaning gain, weaning weight, post-weaning gain and post-weaning feed consumption.

The Data

The data were from the experimental beef breeding herds located at the Fort Robinson Beef Cattle Research Station, Crawford, Nebraska and the Nebraska Agricultural Experiment Station, Lincoln. Birth weight and pre-weaning gain for 283 calves at Lincoln and 677 calves at Fort Robinson were used in this analysis. Post-weaning gain and feed consumption on 351 calves at Lincoln and 733 calves at Fort Robinson were available. All male calves were maintained as bulls for the entire performance period studied. The calves in this study were born in the years 1951 through 1955. Heifers from the 1955 calf crop at Fort Robinson were not individually fed. Two inbred Hereford lines and one each of the Angus and Shorthorn breeds were located at Lincoln. Six Hereford lines and one Angus line were in production at the Fort Robinson Station in 1951. By 1955, ten Hereford and two Angus lines were being carried at Fort Robinson. The average inbreeding coefficients for the calves and their dams at Lincoln were 0.13 and 0.10, respectively. The inbreeding coefficients for the calves and dams at Fort Robinson averaged 0.05 and 0.03, respectively.

Birth weight and average daily gain from birth to weaning were recorded for each calf. Weaning weight at 200 days was computed as birth weight plus 200 times pre-weaning average daily gain. A 168-day feeding period was started 28 days following weaning. During the post-weaning period bulls and heifers were separated at all times and were kept in large lots when they were not tied to the individual feeders. The calves born in 1951 were fed by tying the calves to individual self-feeders for 2 hours in the morning and for a comparable period in the late afternoon. In the succeeding 4 years the calves were tied to their feeders in the evening and turned out in the morning. In all cases feed consumption was limited only by the appetite or capacity of the animals and the time allotted. Gain in weight and feed consumed were recorded for each calf at 28-day intervals. The approximate amount of total digestible nutrients (TDN) consumed was computed using the average values presented by the National Research Council (N.R.C., 1950). The composition of the rations fed at Lincoln and Fort Robinson are given in table 1.

[1] Published with approval of the Director as Paper No. 1107, Journal Series, Nebraska Agricultural Experiment Station.
[2] Contribution from the North Central Regional Project NC-1, Improvement of Beef Cattle through Breeding Methods.
[3] The authors express their appreciation to R. L. Davis and E. W. Schleicher for assistance in collecting the data.

TABLE 1. COMPOSITION OF RATION FED[a] EACH YEAR AT LINCOLN AND FORT ROBINSON

Station	Lincoln	Fort Robinson
1951	45.5% Ground shelled corn 14.0% Oats 7.0% Wheat bran 3.5% Soybean oil meal 30.0% Alfalfa hay	Alfalfa hay
1952	40.0% Ground shelled corn 17.0% Oats 15.0% Dried molasses beet pulp 3.0% Soybean oil meal 25.0% Alfalfa hay	50% Alfalfa hay and 50% Oat hay
1953	38.0% Ground shelled corn 15.0% Ground oats 15.0% Dried molasses beet pulp 7.0% Soybean oil meal 18.8% Alfalfa hay 6.2% Brome hay	Same as 1952
1954	38.0% Ground shelled corn 15.0% Ground oats 15.0% Dried molasses beet pulp 7.0% Soybean oil meal 12.5% Alfalfa hay 12.5% Brome hay	Bulls 50% Alfalfa hay and 50% Oat hay plus 3.5 lb. Rolled barley and soybean oil meal mixture per day Heifers 50% Alfalfa hay and 50% Oat hay
1955	Same as 1954	Bulls Hay same as 1954, plus 4.2 lb. Rolled oats per day Heifers Not individually fed

[a] Fed ad libitum unless otherwise indicated; hay was chopped at both stations.

Method of Analysis

Since the inbreeding coefficients of the calves were related to the inbreeding coefficients of their dams, multiple regression was used to compute the inbreeding effects. For the pre-weaning traits the effects of inbreeding of the calf and inbreeding of the dam were computed simultaneously. The partial regressions of birth weight and pre-weaning average daily gain on inbreeding of the calf and inbreeding of the dam were computed from the pooled sums of squares and cross-products within year-line-age of dam subclasses. The pre-weaning traits were first adjusted for the effect of sex using the multiplicative adjustment derived by Koch *et al.* (1959). The inbreeding effects for weaning weight at 200 days were obtained by adding the effect for birth weight plus 200 times the effect for pre-weaning average daily gain.

The effects of inbreeding of the calf, inbreeding of the dam and age of the calf at the beginning of the test on average daily gain and average daily feed consumption in the 168-day post-weaning feeding period were computed simultaneously. These partial regressions were computed from the pooled sums of squares and cross-products within sex-year-line-sire subclasses for the Fort Robinson data. The Lincoln data were also classified by feeding groups within years since calves were weaned and started on feed in two groups about one month apart. The effects of inbreeding of the calf, inbreeding of the dam and initial age of the calf on total gain and feed consumption in each of six successive 28-day periods were computed simultaneously from the Lincoln data. The regressions of gain and feed consumption for each period on initial age were computed from the Fort Robinson data. Reasons for ignoring inbreeding in the analysis by periods at Fort Robinson will be discussed later.

Results and Discussion

Pre-Weaning Traits

The computed effects of inbreeding of the calf and inbreeding of the dam on birth weight, pre-weaning average daily gain and weaning weight at 200 days are shown with their standard errors in table 2. In many cases the regressions are small compared to their standard errors. The means for each trait at each station are also given in table

TABLE 2. PARTIAL REGRESSIONS [a] OF BIRTH WEIGHT, PRE-WEANING AVERAGE DAILY GAIN AND 200-DAY WEIGHT ON INBREEDING OF CALF AND INBREEDING OF DAM AND PARTIAL REGRESSIONS OF POST-WEANING AVERAGE DAILY GAIN AND FEED CONSUMPTION (TDN) FOR 168-DAYS ON INBREEDING OF CALF, INBREEDING OF DAM AND INITIAL AGE ON TEST WITH THEIR STANDARD ERRORS AND THE AVERAGE OF ALL CALVES FOR EACH TRAIT

Station	Lincoln	Fort Robinson
	Birth weight	
Average birth weight	71.2	74.2
Inbreeding of calf	−.38±0.13	−.06±0.08
Inbreeding of dam	−.03±0.12	0.13±0.08
	Pre-weaning av. da. gain	
Average daily gain	1.69	1.49
Inbreeding of calf	−.0052±0.0028	0.0000±0.0019
Inbreeding of dam	−.0006±0.0028	−.0005±0.0019
	200-day weaning weight	
Average weaning weight	409	372
Inbreeding of calf	−1.42±0.58	−.05±0.39
Inbreeding of dam	−.15±0.58	0.04±0.39
	Post-weaning av. da. gain	
Average daily gain	2.11	1.11
Inbreeding of calf	−.0075±0.0036	−.0033±0.0018
Inbreeding of dam	−.0054±0.0030	0.0035±0.0018
Initial age	−.0017±0.0018	0.0000±0.0006
	Post-weaning av. da. consumption (TDN)	
Average daily feed cons.	9.60	5.74
Inbreeding of calf	−.0208±0.0137	−.0025±0.0071
Inbreeding of dam	−.0170±0.0107	0.0199±0.0077
Initial age	0.0182±0.0071	0.0123±0.0024

[a] Expressed in pounds of weight, daily gain and TDN per percent inbreeding or per day of initial age.

2. At Lincoln, negative effects of both inbreeding of the calf (−.38±0.13 and −.0052 ±0.0028) and inbreeding of the dam (−.03 ±0.12 and −.0006±0.0028) were found for birth weight and pre-weaning daily gain. The effect of inbreeding of the calf on birth weight (−.06±0.08) was also negative at Fort Robinson. However, the effect was smaller than at Lincoln. There was no detectable effect of inbreeding of the calf on pre-weaning average daily gain (0.0000±0.0019) in the Fort Robinson data. In the Fort Robinson data inbreeding of the dam had a positive effect on birth weight (0.13±0.08) and a negative effect on pre-weaning gain (−.0005 ±0.0019). Other analyses reported in the literature indicate negative effects of inbreeding. Koch (1951) found regressions of weaning weight on inbreeding of calf and dam of −.48 and −2.54, respectively. Similar estimates of Burgess *et al.* (1954), were −1.76 and −1.15.

At Lincoln, the average inbreeding coefficients of the lines increased steadily over a period of years. The inbreeding in the Fort Robinson lines occurred rather irregularly during the early years of the formation of the lines in which the data for this analysis were taken. For example, some lines were formed from two groups of half-sisters, the sire being a half-brother to one group of cows. The half-sib groups containing the sire were usually non-inbred and the other group of cows were in general, at low levels of inbreeding. Thus calves from non-inbred cows were inbred and calves from inbred cows were themselves not inbred. While unbiased estimates of inbreeding effects should result from such data, more consistent results might be expected from lines showing a somewhat more regular increase in inbreeding like the lines at Lincoln.

Most of the dams in the Fort Robinson analysis had coefficients of inbreeding of zero while a few had coefficients of from 0.2 to 0.3. Thus a few animals contributed excessively to the estimates of the inbreeding effects at Fort Robinson permitting factors other than inbreeding to predominate in the results measured. Because of the low levels of inbreeding at Fort Robinson and the inconsistent results obtained, the traits studied here were not adjusted for inbreeding in subsequent analyses of the Fort Robinson data.

Post-Weaning Traits

The effects of inbreeding of the calf, inbreeding of the dam and age at the beginning of the post-weaning feeding period on 168-day post-weaning average daily gain and feed consumption are given in table 2 with their standard errors. The means of these traits are also given in table 2. The effects of inbreeding of the calf, inbreeding of the dam and initial age on gain and feed consumption in successive 28-day periods at Lincoln are given in table 3. Table 3 also includes the simple regressions of gain and feed consumption on initial age at Fort Robinson for each 28-day period. The regressions in table 3 are expressed in pounds of gain or feed (TDN) consumed per 28-day period for each percent inbreeding or day of initial age. The upper figures are the computed regressions while the lower figures represent values used to adjust data in future analyses.

Effects of Inbreeding of Calf. Inbreeding of the calf depressed both 168-day average daily gain and feed consumption at Lincoln ($-.0075\pm0.0036$ and $-.0208\pm0.0137$) and at Fort Robinson ($-.0033\pm0.0018$ and $-.0025\pm0.0071$) (table 2). The partial regressions of period gain and feed consumption on inbreeding of the calf for Lincoln were primarily negative (table 3). The values varied considerably from period to period with positive effects on gain existing for the second and last periods. Since no time trend was apparent, the average of the six regressions was used as the adjustment for each period for both gain and feed consumption. According to Stonaker (1954), calves from inbred lines had lower feed lot gains and utilized feed less efficiently than outbred calves.

Effects of Inbreeding of Dam. Inbreeding of the dam had a negative effect on growth rate ($-.0054\pm0.0030$) and feed consumption ($-.0170\pm0.0107$) at Lincoln. The linear regressions of the inbreeding of dam effect for gain and feed consumption on successive periods were found to be $-.05$ and $-.06$, respectively at Lincoln. The actual adjustments shown in table 3 for inbreeding of dam were computed using this linear relationship between the partial regressions and successive time intervals. A positive effect on growth rate (0.0035 ± 0.0018) and feed consumption (0.0199 ± 0.0077) was

TABLE 3. PARTIAL REGRESSIONS[a] OF POST-WEANING GAIN AND FEED CONSUMPTION (TDN) FOR SIX CONSECUTIVE 28-DAY PERIODS ON INBREEDING OF CALF, INBREEDING OF DAM AND INITIAL AGE ON TEST

Post-weaning periods[b]	1	2	3	4	5	6
Station			Lincoln			
			28-day gain			
Inbreeding of calf	−.14	0.06	−.65	−.21	−.41	0.09
	−.21	−.21	−.21	−.21	−.21	−.21
Inbreeding of dam	−.09	0.03	−.13	−.16	−.35	−.21
	−.02	−.07	−.12	−.17	−.22	−.27
Initial age	0.05	0.06	−.08	0.01	−.35	0.03
	0.00	0.00	0.00	0.00	0.00	0.00
			28-day feed consumption (TDN)			
Inbreeding of calf	−.02	−.55	−1.05	−.78	−.64	−.45
	−.58	−.58	−.58	−.58	−.58	−.58
Inbreeding of dam	−.36	−.39	−.36	−.64	−.41	−.75
	−.33	−.39	−.45	−.51	−.57	−.63
Initial age	0.80	0.44	0.61	0.33	0.44	0.33
	0.69	0.61	0.53	0.45	0.37	0.29
Station			Fort Robinson			
			28-day gain			
Initial age	−.03	0.12	0.03	−.09	0.14	−.19
	0.00	0.00	0.00	0.00	0.00	0.00
			28-day feed consumption (TDN)			
Initial age	0.46	0.47	0.37	0.23	0.45	0.10
	0.50	0.44	0.38	0.32	0.26	0.20

[a] Expressed in pounds of gain and TDN for the 28-day period per percent inbreeding or day of initial age.
[b] Computed regression above, regression used to adjust below.

found at Fort Robinson (table 2). The most tenable explanation of the results of the Fort Robinson analysis is that the few cows which had high coefficients of inbreeding were genetically better than average for growth rate. Their calves were heavy at birth and gained well in the post-weaning period, however the inbreeding effect on mothering ability during the nursing period, perhaps milk production primarily, was strong enough to depress pre-weaning gain.

Effects of Age. The regressions of 28-day gain by periods on initial age at Fort Robinson varied around zero with no noticeable trend which indicated that growth through the post-weaning period was nearly linear. At Lincoln each additional day of age at the beginning of the feeding period meant an average of 0.0017 lb. less gain per day for the 168-day feeding period. Computing this regression for each 28-day period showed that the negative effect of initial age on gain found for the 168-day period was due almost entirely to the negative effect occurring in the fifth 28-day period (table 3). It would seem that chance more nearly explains the negative effect of age on post-weaning gain than does a hypothesis of curvilinear growth, since the Lincoln calves were only 13 months old and averaged about 770 lb. at the end of the feeding period. Also, the effect of initial age on gain made during the sixth and final 28-days was positive (table 3).

The regression of consumption on initial age showed that the older calves at both stations consumed more feed on the average than did the younger calves. This was expected since age was associated closely with weight. The increased consumption for older calves may have been required for increased maintenance since the older calves did not gain faster. The range in age was rather narrow and the results found here would not be expected to apply to calves vs. yearlings, for example.

The magnitude of the effect of initial age on feed consumption by periods decreased throughout the feeding period for both stations (table 3). To the extent that initial age affects consumption through its relationship with size, the decreasing values for the regressions reflect that weaning age is associated more closely with size soon after weaning than with size later in the feeding period. The actual adjustments used resulted from computing the linear regression of the age effects on periods. The changes per 28-day period in the effects were —.08 for Lincoln and —.06 for Fort Robinson.

Conclusions

The inbreeding effects computed from the Lincoln and Fort Robinson data were not in agreement. In general, calves with higher than average inbreeding coefficients were below average in performance for the traits studied. However, the magnitude of the effects was quite different at the two stations for each trait. The standard errors indicate that sampling variance could account for the discrepancies between stations in some cases but were not likely to in others.

The effect of inbreeding of the dam was negative for all traits at Lincoln but positive for most traits at Fort Robinson. These results from the Fort Robinson data could not be explained by any variables evaluated in this study and were attributed to chance.

The effects of initial age on the post-weaning traits were computed simultaneously with the inbreeding regressions. Initial age had little effect on subsequent feed lot gain, however, older calves consumed more feed than the younger calves. This effect of initial age on feed consumption decreased as the feeding period progressed.

From the two sets of estimates obtained here and the other values reported from the literature, it is evident that considerably more data would be required to obtain accurate estimates of the magnitude of the inbreeding depression to be expected in beef cattle. In general the results of this analysis support the results obtained from other studies in that increased inbreeding leads to decreased feed consumption and growth rate.

Literature Cited

Burgess, J. B., Nellie L. Landblom and H. H. Stonaker. 1954. Weaning weight of Hereford calves as affected by inbreeding, sex and age. J. Animal Sci. 13:843.

Koch, R. M. 1951. Size of calves at weaning as a permanent characteristic of range Hereford cows. J. Animal Sci. 10:768.

Koch, R. M., K. E. Gregory, J. E. Ingalls and R. L. Arthaud. 1959. Evaluating the influence of sex on birth weight and pre-weaning gain in beef cattle. J. Animal Sci. 18:738.

N.R.C. 1950. Nutrient Requirements of Domestic Animals, Number IV. Nutrient Requirements of Beef Cattle. National Research Council, Washington, D. C.

Stonaker, H. H. 1954. Observations on reproduction, growth, feed utilization and grade of inbred and outbred Hereford cattle. J. Animal Sci. 13:963. (Abstr.)

HERITABILITY OF CARCASS LENGTH, CARCASS BACKFAT THICKNESS AND LOIN LEAN AREA IN SWINE

FRANK D. ENFIELD[1] AND J. A. WHATLEY, JR.

Oklahoma Agricultural Experiment Station, Stillwater[2]

THERE has been an increased amount of emphasis placed on the need for more lean meat and less fat in pork cuts during the past several years. In an attempt to improve the meatiness of pork carcasses the various swine breed associations have set up meat-type certification programs to identify individuals or lines that can contribute most to the improvement of carcass merit. Carcass backfat thickness, carcass length, and loin lean area are the carcass traits that are used in the certification programs. If selection is to be based on the carcass evaluation of these traits it is important to know the amount of genetic variation and the heritability of each trait as well as the genetic relationships among the traits themselves. A knowledge of these factors and of the economic importance of each trait as reflected in the net value of the carcass are important considerations in determining the emphasis to be placed on each trait in a selection program. The objectives of this study were to gain further knowledge concerning the heritability of carcass backfat thickness, carcass length, and loin lean area and to determine the phenotypic and genetic relationships among these traits.

Materials and Methods

The data used in this study were obtained from 531 carcasses of pigs slaughtered in the swine breeding project at the Oklahoma Agricultural Experiment Station in cooperation with the Regional Swine Breeding Laboratory. From this number, 304 carcasses were from the Stillwater station and 227 were from Fort Reno. The Stillwater data were obtained over a period of 7 seasons, from 1953 to 1957, while the data from Fort Reno were collected in 5 seasons over the same period. Pigs from the Fort Reno station were slaughtered by Wilson and Company, Oklahoma City. Backfat thickness and carcass length measurements were made on the chilled carcasses at the packing plant. The loins from these carcasses were purchased and brought to the college meat laboratory for loin lean area measurements. Except for a small number of pigs the Stillwater carcasses were processed at the college meat laboratory. Pigs which were not slaughtered at the meat laboratory were handled in the same manner as the Fort Reno carcasses. Pigs of Duroc, Beltsville No. 1 and Hampshire breeding were used in the study. Carcasses from 497 barrows and 34 gilts were processed. The data on the gilts were adjusted to a barrow equivalent. The correction factors used in adjusting a gilt to a barrow equivalent were as follows: carcass length, —.25 inches; backfat thickness, .13 inches; and loin lean area, —.35 square inches.

The analysis of variance in a nested classification with unequal sub-class numbers used in determining variance components and to estimate heritability were described by King and Henderson (1954) and served as the basis for the present analysis. The statistical model for the analysis of the data adjusted for sex is as follows:

$$Y_{ijkl}=u+a_i+s_{ij}+d_{ijk}+e_{ijkl}$$

where Y_{ijkl} is the observed phenotypic value of the l^{th} pig from the k^{th} dam mated to the j^{th} sire in the i^{th} station-season farrowing.

The corresponding analysis of variance used in estimating the sire, dam, and within full-sib family components of variance from which the estimates of heritability were obtained are given in table 1. The variance components were determined by equating expected mean squares to computed mean squares and substituting the known elements of the equation. Heritability estimates were then obtained from the components of variance by the paternal half-sib correlation, maternal half-sib correlation and the full-sib correlation.

Phenotypic correlations were determined for the three carcass traits with all analyses of variance and covariance calculated on an intra-season, intra-station basis to eliminate

[1] Present address University of Minnesota, St. Paul, Minnesota.

[2] Animal Husbandry Department in cooperation with the Regional Swine Breeding Laboratory, AHRD, ARS, U.S.D.A.

TABLE 1. THEORETICAL ANALYSIS OF VARIANCE FOR DETERMINING COMPONENTS OF VARIANCE

Source of variation	d.f.	Variance components and coefficients
Among farrowings	f-1	
Among sires within farrowings	s-f	$E+k_2D+k_3S$
Among dams within sires and farrowings	d-s	$E+k_1D$
Within full-sib families and farrowings	T-d	E

f = Number of farrowing seasons at all stations.
s = Number of sires.
d = Number of dams.
T = Total number of carcasses.
E = Variance due to differences among full-sibs.
D = Variance due to differences among dams.
S = Variance due to differences among sires.

$$k_1 = \frac{1}{d-s}\left[T - \sum_i \sum_j \frac{1}{n_{ij}} \sum_k n^2_{ijk}\right]$$

$$k_2 = \frac{1}{s-1}\left[\sum_i \sum_j \frac{1}{n_{ij}} \sum_k n^2_{ijk} - \frac{1}{T}\sum_i \sum_j \sum_k n^2_{ijk}\right]$$

$$k_3 = \frac{1}{s-1}\left[T - \frac{\sum_i \sum_j n^2_{ij}}{T}\right]$$

n_{ijk} = Number of carcasses from k^{th} dam, j^{th} sire, and i^{th} farrowing.
n_{ij} = Number of carcasses from j^{th} sire in the i^{th} farrowing.

any effects of time trends or changes in management. Genetic correlations were calculated from the sire components of variance and covariance for the three traits considered.

Results and Discussion

The means, standard deviations and coefficients of variation computed on an intra-season and station basis are summarized in table 2. The mean squares obtained in the analysis of variance for each trait are given in table 3. Significant differences were found among farrowings, among sires, and among dams for carcass length and backfat thickness.

The highly significant mean square for farrowings in the analysis for loin lean area can be attributed to the change in measurement technique during the study since the data from the first two seasons at Stillwater consisted of width x depth measurements taken at the last rib. All other loin lean area measurements were planimeter readings taken at the tenth rib. Differences among dams were not significant for loin lean area.

TABLE 2. MEANS, STANDARD DEVIATIONS AND COEFFICIENTS OF VARIATION (CORRECTED FOR SEX AND COMPUTED ON AN INTRA-SEASON AND INTRA-STATION BASIS)

Trait	Mean	Standard deviation	Coefficient of variation
Carcass length, in.	29.2	0.78	2.7
Backfat thickness, in.	1.66	0.16	9.6
Loin lean area, sq. in.	4.05	0.50	12.3

The analyses of covariance between the three traits being considered and from which the sire components of covariance were calculated to determine the genetic correlations are given in table 4. In the analysis of covariance between carcass length and loin lean area the sire mean product was smaller than the mean product for dams within sires which resulted in a negative estimate for the sire component of covariance even though both mean products were positive.

Estimates of heritability for the three traits obtained from the intra-class correlations are summarized in table 5. The estimates obtained by all three methods of analysis for carcass length are in close agreement with the estimates of Lush (1936), Johansson and Korkman (1950), Stothart (1947), Anderson (1954), and Fredeen and Jonsson (1957). Almost identical estimates were obtained by the three methods in this study, indicating that dominance variation and maternal influences are of little consequence in the phenotypic expression for carcass length.

The paternal half-sib correlation estimate

TABLE 3. ANALYSIS OF VARIANCE FOR CARCASS TRAITS

Source of variation	Carcass length[a] d.f.	Carcass length[a] Mean square	Backfat thickness[a] d.f.	Backfat thickness[a] Mean square	Lean loin area[a] d.f.	Lean loin area[a] Mean square
Farrowings	11	2.82*	11	0.3449**	7	30.1942**
Sires	57	1.23**	57	0.0548	38	0.6022**
Dams	191	0.63**	191	0.0317**	123	0.2187
Littermates	271	0.46	271	0.0194	167	0.2059

* Significant at .05.
** Significant at .01.
[a] The unit of measurement for carcass length and backfat thickness was in inches. Loin lean area was measured in square inches.

TABLE 4. ANALYSIS OF COVARIANCE FOR CARCASS TRAITS

Source of covariation	Carcass length with backfat thickness		Carcass length with loin lean area		Backfat thickness with loin lean area	
	d.f.	Mean product	d.f.	Mean product	d.f.	Mean product
Sires	57	—.092	38	0.026	38	—.035
Dams/sires	191	—.069	123	0.094	123	—.025

of 0.79 for loin lean area in the present study is larger than other workers have reported, but is in relatively close agreement with DePape (1954) and Fredeen (1953). The estimate of 0.44 is in close agreement with the average of other estimates reported and summarized by Craft (1958).

TABLE 5. ESTIMATES OF HERITABILITY

Trait	4S	4D	2(S+D)
	S+D+E	S+D+E	S+D+E
Carcass length	0.50	0.54	0.52
Backfat thickness	0.42	0.84	0.63
Loin lean area	0.79	0.10	0.44

Estimates of heritability for backfat thickness have been moderate to high in most of the work reported (Lush, 1936; Stothart, 1947; Dickerson, 1947; Johansson and Korkman, 1950; Fredeen, 1953). Evidence from the current study gives further indication that the additive genetic variance for backfat thickness makes a major contribution to the total phenotypic variance.

The phenotypic and genetic correlations for the traits under consideration are given in table 6.

TABLE 6. PHENOTYPIC AND GENETIC CORRELATIONS

Trait	Carcass length	Backfat thickness
Carcass length	....	—.36* phenotypic
	....	—.19 genetic
Loin lean area	0.10 phenotypic	—.27* phenotypic
	—.14 genetic	—.10* genetic

* Significant at .01 level.

Other studies reported in the literature regarding the relationships among these traits have been inconsistent especially in the correlations involving carcass length. Correlations between backfat thickness and carcass length have usually been negative, but the magnitude has varied considerably (Aunan and Winters, 1949; Brown *et al.*, 1951; Fredeen, 1953). Estimates of phenotypic correlations between loin lean area and carcass length have varied from —.18 (Stothart, 1938) to 0.38 (Aunan and Winters, 1949). The negative phenotypic correlation of —.27 between backfat thickness and loin lean area is consistent with estimates reported by Whiteman and Whatley (1953) and Hazel and Kline (1952). The phenotypic and genetic correlations obtained between carcass length and loin lean area were both small but opposite in sign. The negative genetic correlation between these traits is consistent with the —.16 estimate of Fredeen (1953).

Evidence from this study based on the genetic correlations obtained indicates that selection for backfat thickness or loin lean area should be slightly effective in reducing carcass backfat and increasing loin lean area. Although carcass length appears to be quite highly heritable it has only a moderate relationship to measures of carcass leanness. On this basis there seems to be little value in including carcass length in a selection program if the improvement in the meatiness of the carcass is the main objective.

Summary

Data from 531 carcasses from the swine breeding project were used in this study to estimate the heritability of carcass length, carcass backfat thickness and loin lean area, and to determine the phenotypic and genetic correlations between these traits. Heritability estimates obtained by intra-class correlations from components of variance indicated that all three traits are moderately heritable in the range of 0.4 to 0.6. Phenotypic correlations calculated on an intra-season, intra-station basis were small in absolute magnitude with the largest correlations being a —.36 between backfat thickness and carcass length and —.27 between backfat thickness and loin lean area. The genetic correlations between the three traits were all negative but small in absolute magnitude.

Literature Cited

Anderson, D. E. 1954. Genetic relations between carcass characters, rate and economy of gain. Ph.D. Thesis. Iowa State University, Ames, Iowa.

Aunan, W. J. and L. M. Winters. 1949. A study of the variation of muscle, fat and bone of swine carcasses. J. Animal Sci. 8:182.

Brown, J. C., J. C. Hillier and J. A. Whatley Jr. 1951. Specific gravity as a measure of the fat content of the pork carcasses. J. Animal Sci. 10:97.

Craft, W. A. 1958. Fifty years of progress in swine breeding. J. Animal Sci. 17:960.

DePape, J. G. 1954. Swine carcass studies. I. Genetic variation and covariation in carcass characteristics. II. The probe as an indicator of carcass merit. Ph.D. Thesis. Oklahoma State University, Stillwater, Oklahoma.

Dickerson, G. E. 1947. Composition of hog carcasses as influenced by heritable differences in rate and economy of gain. Ia. Agr. Exp. Sta. Bul. 354.

Fredeen, H. T. 1953. Genetic aspects of Canadian bacon production. Dept. of Agr., Ottawa, Canada. Pub. 889.

Fredeen, H. T. and Per Jonsson. 1957. Genic variance and covariance in Danish Landrace swine as evaluated under a system of individual feeding of progeny test groups. Zeit. Tierz. Züchtungsbiol. 70:348.

Hazel, L. N. and E. A. Kline. 1952. Mechanical measurement of fatness and carcass value on live hogs. J. Animal Sci. 11:313.

Johansson, I. and N. Korkman. 1950. A study of variation in production traits of bacon pigs. Acta. Agr. Scandinavica 1:62.

King, S. C. and C. R. Henderson. 1954. Variance component analysis in heritability studies. Poul. Sci. 33:147.

Lush, J. L. 1936. Genetic aspects of the Danish system of progeny testing swine. Ia. Agr. Exp. Sta. Res. Bul. 204.

Stothart, J. G. 1938. A study of factors influencing swine carcass measurements. Sci. Agr. 19:162.

Stothart, J. G. 1947. A study of parental progeny correlations with Canadian bacon hogs. Sci. Agr. 27:354.

Whiteman, J. V. and J. A. Whatley Jr. 1953. An evaluation of some swine carcass measurements. J. Animal Sci. 12:591.

USE OF NATURALLY OCCURRING POTASSIUM-40 TO DETERMINE THE CARCASS COMPOSITION OF LIVE SHEEP

A. H. KIRTON, A. M. PEARSON, R. H. NELSON, E. C. ANDERSON AND R. L. SCHUCH

Michigan Agricultural Experiment Station and Los Alamos Scientific Laboratory [1, 2]

RECENT research work has suggested that the radioactivity of a naturally occurring isotope of potassium (K^{40}) might be used to estimate the carcass and body composition of the live animal. Potassium-40 has been shown to be present in a constant ratio in naturally occurring potassium (Vinogradov, 1957), while potassium is known to be a relatively constant proportion of muscular tissue (Ciba, 1958; Mounib and Evans, 1960). Woodward *et al.* (1956) indicated that the K^{40} gamma activity of human subjects might be used to estimate their muscle mass. Similarly, Zobrisky *et al.* (1959) have reported that the K^{40} content of live hogs may possibly be useful as a rapid non-destructive index for determining meatiness. The composition of pork hams has been successfully estimated from their K^{40} content (Kulwich *et al.*, 1958; Kulwich *et al.*, 1960a; Kulwich *et al.*, 1960b). Anderson (1959) published a theoretical paper on the application of natural gamma activity for predicting meat composition. Allen *et al.* (1960) have reported agreement within $\pm$ 5 percent between the weights of lean body solids for humans as determined by K^{40} and by body density and by body water.

Thus, research work suggests that the measurement of the potassium content of the live animal from the radioactivity of K^{40} might be a useful measure of composition. Therefore, this study was designed to measure the accuracy with which the carcass composition of lambs could be estimated from the natural gamma activity of the live animals and their carcasses.

Materials and Methods

Counter. The Los Alamos four *pi* liquid scintillation counter which has been described by Anderson (1958) was used to measure gamma activity. This is a well-type counter which can accommodate samples weighing up to 300 lb. The sample well is 18 in. in diameter and six ft. in length, and is surrounded by a gamma-sensitive layer of liquid scintillator 6 in. in thickness. The geometrical efficiency approaches 100% and makes a very short counting time possible.

In order to eliminate possible interference from the gamma activity of the fission product Cs^{137}, which is present to a small extent as a result of fallout from nuclear weapon testing (Langham and Anderson, 1959), the potassium determination is based only on those gamma rays which deposit more than 0.8 Mev in the scintillator. A simultaneous measurement of the counting rate due to the gamma rays of lower energies permits the calculation of actual Cs^{137} concentrations.

Animals. Ten recently shorn blackfaced lambs with a mean liveweight of 88 lb. were purchased from a feedlot in Southern Colorado and transported to Los Alamos, New Mexico.

Counting and Sampling. Because of the possibility of potassium and other radioactive contamination on the wool and skin, counts were made on live lambs before and after they had been thoroughly washed with detergent and warm water. It was found that the second washing did not reduce the gamma activity below the level accomplished by one washing. The animals were restrained for counting in a cardboard drum. After being counted, the lambs were slaughtered and dressed in the usual manner. The carcasses and the non-carcass components of the animals were counted for K^{40} activity. The non-carcass components included the hide, feet, head, blood and also all of the internal organs and their contents. Three 100-second counting periods were used in all cases, except for the carcasses which were counted for five 100-second periods.

The carcasses were physically separated

[1] Journal Article 2789, Michigan Agricultural Experiment Station, East Lansing.

[2] The authors gratefully acknowledge the assistance of Mr. and Mrs. Frank Montoya of Los Alamos Scientific Laboratory for their helpfulness throughout the experiment. The authors also express their thanks to Mr. Leslie S. Porter, County Agricultural Agent at LaJara, Colorado, and to Mr. J. R. Chavez, County Agricultural Agent at Sante Fe, New Mexico, for assistance in locating and purchasing the animals used in this study.

into fat, lean and bone, and each component was counted separately for K^{40} activity. The fat and lean were then ground separately and sampled for chemical analyses.

Chemical Analyses. Water and protein were determined according to the procedure of Benne *et al.* (1956). Analysis for ether-extract was carried out according to a modification of the method of Benne *et al.* (1956) as described by Orme *et al.* (1958).

Potassium Estimations. Total potassium was estimated from K^{40} counts. The raw counting data and efficiency calibrations were entered on punched cards, and calculations of the total grams of potassium per kilogram of material were carried out on an I.B.M. electronic computer, which tabulated and printed the results (Anderson *et al.*, 1959).

Results and Discussion

The weights and composition of the lambs are presented in table 1. It may be noted that the variation in liveweight was not extreme. The range of separable components in the carcasses amounted to about 18% in fat content and 10% in lean content. The data on the chemical composition of the boneless carcasses show that the range in percentage for both fat and moisture was 20.1 and for protein 4.3.

The total estimated potassium content of the live lambs and their components is presented in table 2. Washing the lambs reduced the potassium content by 0.94 gm. of potassium per kg. liveweight, or on the average 38 gm. of potassium was removed from each animal by washing. Analysis of variance showed that the difference in potassium content between the washed and unwashed lambs was highly significant. While the potassium activity dropped to 0.65 of its original value, with a standard deviation of 0.07, the apparent total amount of Cs^{137} present remained at 0.99 of the unwashed level, with a standard deviation of 0.12. This strongly suggests that the activity removed was actually potassium. The natural activities of radium and thorium contribute many more counts to the lower energy channel than does potassium, and the main fission products in fallout such as Ru^{103} and Rh^{106} are counted almost exclusively in the lower channel. If any of these activities were being removed, the apparent Cs^{137} activity would drop significantly. The presence of potassium in the wool is not difficult to account for, since the external secretions of the sheep are rich in potassium much of which is trapped in the wool.

TABLE 1. WEIGHT AND COMPOSITION OF TEN LAMBS

Item	Mean	S.D.	Range
Liveweight, lb.	87.9	9.5	76.6-105.5
Hot carcass weight, lb.	45.7	5.9	38.2– 56.3
Non-carcass components, lb.	42.3	3.9	35.6– 48.5
Carcass composition			
Separable fat, lb.	9.7	3.5	4.1– 14.1
Separable fat, %	20.8	5.9	9.7– 27.8
Separable lean, lb.	27.1	3.1	23.4– 33.0
Separable lean, %	59.4	3.2	55.3– 65.5
Bone, lb.	7.5	0.9	6.1– 8.4
Bone, %	16.5	2.1	14.4– 20.4
Edible carcass composition			
Ether-extract, %	22.7	6.9	9.1– 32.5
Protein, %	15.7	1.4	14.0– 18.3
Water, %	60.9	5.6	52.7– 72.8

TABLE 2. POTASSIUM CONTENT OF TEN LIVE LAMBS AND THEIR COMPONENTS AS ESTIMATED FROM K^{40} COUNTS

Item	Mean gm. K/Kg. wt.	S.D.	Range	Counting errors[a] S.D. (%)
Live unwashed	2.71	0.30	2.29–3.16	2.29
Live washed	1.77	0.20	1.47–2.09	3.56
Carcass	2.25	0.33	1.71–2.62	3.68
Non-carcass components	1.78	0.39	0.94–2.33	6.56
Separable fat	0.70	0.44	0.13–1.54	66.41
Separable lean	2.98	0.20	2.67–3.19	5.35
Separable bone	1.41	0.48	0.71–2.06	34.85

[a] Standard deviation computed by method described by Comar (1955) expressed as a percent of total counts based on mean sample count (10 observations) and mean background count.

No satisfactory explanation can be given for the fact that the total potassium content on adding the carcass and the non-carcass components together was greater than the potassium content for the live washed lambs. A highly significant correlation of 0.84 was found between the potassium content of the carcass and the non-carcass components. Since much of the intracellular fluid, which contains potassium, is present in the non-carcass components, a positive relationship must necessarily exist between the potassium content of the carcass and non-carcass components in order to accurately predict carcass composition from gamma counts for the live animal. It is interesting to note that there was a measurable amount of gamma activity from the separable fat and bone, although the counting errors of these determinations were quite large (table 2), indicating that these figures are relatively inaccurate. However, it was not surprising to find potassium in the

bones, since slight amounts of lean tissue were attached and the bones also contained the marrow, which includes most of the hemopoietic tissue of the body. The data in table 2 show that the major source of potassium in the sheep carcass is the muscular tissue, while the relatively low standard deviation shows that the proportion of potassium in this tissue is relatively constant.

TABLE 3. CORRELATIONS BETWEEN THE POTASSIUM CONTENT OF LIVE LAMBS AND CARCASSES AND CARCASS COMPOSITION

Item	Live unwashed gm. K/Kg. wt.	Live washed gm. K/Kg. wt.	Carcass gm. K/Kg. wt.
Live washed lambs, gm. K/Kg. wt.	0.66*	....	....
Carcass, gm. K/Kg. wt.	0.30	0.40	....
Separable fat, %	−0.79**	−0.73*	−0.38
Separable lean, %	0.57	0.58	0.52
Separable bone, %	0.86**	0.78**	0.14
Edible carcass			
Fat, %	−0.79**	−0.71*	−0.41
Water, %	0.77**	0.65*	0.40
Protein, %	0.80**	0.83**	0.41

* Correlation significant at 5% level.
** Correlation significant at 1% level.

Table 3 shows the relationships between the potassium content of the lambs and the other variables. While most of the carcass potassium was present in muscular tissue, the correlation between measured potassium content of the live animal and the lean content of the carcass was not significant. This unexpected result can perhaps be explained in part by the small variability of the percent lean in this group of animals. As table 1 shows, the percent separable lean of the 10 carcasses showed a standard deviation of 3.2%. However, the counting statistical error as given in table 2 is 5.3%. Since the variability of the carcasses as determined by dissection is less than the precision of the potassium measurement, a significant correlation would not be expected.

Percent separable fat would be expected to show a negative correlation with potassium concentration, since fat contains little potassium. The dissection data show a larger variability of fat than of lean (5.9% versus 3.2%) and a significant negative correlation was observed between potassium and fat. However, the variability of the fat was comparable with the counting precision, and the correlation was not good enough for practical applications. The reason for the positive correlation with bone is not clear. It is known that percent bone tends to follow muscle percent in growing animals, but the variability of bone in these animals was even less than the variability of separable lean. Although it might be anticipated that skin and wool contamination of the unwashed lambs would reduce the relationship between the amount of potassium in the live animal and carcass composition, for some unknown reason the opposite situation was found to be the case. In general, washing lowered the correlations between the potassium content of the live animal and the various carcass components.

As all counts have been related to carcass composition, it was expected that the potassium content as estimated from counts on the actual carcass with non-carcass potassium sources removed should be most closely related to carcass composition. However, this was not found to be the case, as none of the correlation coefficients between carcass potassium content and percent of the separable components of the carcasses were significant.

The correlations between the potassium content of the 10 lambs and the chemical composition of the edible portion of their carcasses are also presented in table 3. As was the case for separable tissues, significant relationships were found with counts for the live animal but not for the carcass. The highest relationships were found between the potassium content of the live animal and the percent protein in the edible tissue. This would be expected if most of the potassium were present in the muscular tissue or lean. Since most of the body potassium is present in the intracellular fluid (Ciba, 1958; Conway, 1957; Robinson, 1960) and most of the carcass intracellular fluid is present in muscular tissue, it might be expected that the highest relationships to K^{40} would be with percent lean in the carcass and/or with percent protein in the edible carcass. It is likely that the small number of animals and the fact that there was a low range in percent separable carcass lean explained the lack of a significant correlation between the proportion of potassium in the live lambs and carcasses and the percent lean in their carcasses. However, the lack of a correlation with lean even though the total range in lean is fairly low, indicates that the relationship does not have the desired accuracy for determining differences in composition. The above range

of composition was one over which an experimenter may wish to determine treatment effects in a critical experiment.

Evans (1954), Evans and King (1955), and Kidwell *et al.* (1959) have shown that the red cells of individual sheep may be classed as either high potassium (approximately 83-m-equiv. per litre of erythrocytes) or low potassium (approximately 23-m-equiv. per litre). The differences were reported to have a genetic basis. Obviously, if this were true for muscle potassium, the presence of both types of sheep in a sample would reduce the usefulness of potassium for predicting composition. Mounib and Evans (1960), however, have shown that the potassium content of the skeletal muscle of sheep of the two different blood types was not significantly different, athough it tended to vary slightly in the same direction as blood potassium. The low standard deviation in grams of potassium per kilogram weight for the separable lean (table 2) indicates that differences in the proportion of potassium between sheep was not an important factor in explaining the poor relationships noted in the present study.

Table 4 gives the standard errors of the regression equations, which could be used for estimating carcass composition and indicates the size of the errors which would be made from such predictions. The regression equations between the variables with the highest correlations were chosen. Although the standard errors of the equations for predicting the protein content of the edible carcass appear to be relatively low, these relationships do not allow a great deal of discrimination between animals, since the range in protein was only 4.3%.

TABLE 4. STANDARD ERRORS OF REGRESSION EQUATIONS FOR PREDICTING CARCASS COMPOSITION

Dependent variable	Independent variable	Standard error [a]
Separable fat, %	g. K/Kg. wt. (live unwashed)	4.0%
Bone, %	g. K/Kg. wt. (live unwashed)	1.1%
Protein, % (edible tissue)	g. K/Kg. wt. (live unwashed)	1.0%
Protein, % (edible tissue)	g. K/Kg. wt. (live washed)	0.8%
Fat, % (edible tissue)	g. K/Kg. wt. (live unwashed)	4.4%
Fat, % (edible tissue)	g. K/Kg. wt. (live washed)	5.1%

[a] Expressed as a % of carcass weight or as a % of the boneless carcass.

Summary

Ten lambs were used to determine the usefulness of K^{40} for predicting carcass composition from counts made on the live animals and their carcasses. It was found that washing the animals removed a significant amount of potassium contamination from the skin and wool of shorn lambs. The highest potassium concentrations were found in the separable lean tissue of the carcass with the bone and fat containing lesser amounts. No significant correlations were found between carcass composition and the gamma activity of the carcasses, partly because of the limited variability among the animals in comparison with the counting precision. Although significant correlations were found between the gamma activity of the live animals and their carcass composition, in general, these relationships did not appear high enough to be of practical importance.

Literature Cited

Allen, T. H., E. C. Anderson and W. H. Langham. 1960. Total body potassium and gross body composition in relation to age. J. Gerontol. 15:348.

Anderson, E. C. 1958. The Los Alamos Human Counter. p. 211. Liquid Scintillation Counting. Pergamon Press, New York—London.

Anderson, E. C. 1959. Applications of natural gamma activity measurements to meat. Food Research 24:605.

Anderson, E. C., B. Clinton and J. L. Shields. 1959. Gamma radioactivity of people and milk. Los Alamos Scientific Laboratory Report LA-2296. OTS, U. S. Dept. of Commerce, Washington, D. C.

Benne, E. J., N. H. Van Hall and A. M. Pearson. 1956. Analysis of fresh meat. J. Assoc. Official Agr. Chem. 39:937.

Ciba, 1958. Ciba Foundation Colloquia on Aging. IV. Water and Electrolyte Metabolism in Relation to Age and Sex. pp. 15, 102, 199. Little, Brown and Company, Boston.

Comar, C. L. 1955. Radioisotopes in Biology and Agriculture. p. 173. McGraw-Hill Book Company, Inc., New York.

Conway, E. J. 1957. Nature and significance of concentration relations of potassium and sodium ions in skeletal muscle. Physiol. Rev. 37:84.

Evans, J. V. 1954. Electrolyte concentrations in red blood cells of British breeds of sheep. Nature 174:931.

Evans, J. V. and J. W. B. King. 1955. Genetic control of sodium and potassium concentrations in the red blood cells of sheep. Nature 175:171.

Kidwell, J. F., V. R. Bohman, M. A. Wade, L. H. Haverland and J. E. Hunter. 1959. Evidence of genetic control of blood potassium concentration in sheep. J. Heredity 50:275.

Kulwich, R., L. Feinstein and E. C. Anderson. 1958. Correlation of potassium-40 concentration and fat-free lean content of hams. Science 127:338.

Kulwich, R. L. Feinstein and C. Golumbic. 1960a. Beta radioactivity of the ash in relation to the composition of ham. J. Animal Sci. 19:119.

Kulwich, R., L. Feinstein, C. Golumbic, R. L. Hiner, W. R. Seymour and W. R. Kauffman. 1960b. Relationship of gamma ray measurements to the lean content of hams. J. Animal Sci. 19:1238.

Langham, W. H. and Anderson, E. C. 1959. Cs-137 biospheric contamination from nuclear weapons tests. Health Phys. 2:30.

Mounib, M. S. and J. V. Evans. 1960. The potassium and sodium contents of sheep tissues in relation to the potassium content of the erythrocytes and the age of the animal. Biochem. J. 75:77.

Orme, L. E., A. M. Pearson, L. J. Bratzler and W. T. Magee. 1958. Specific gravity as an objective measure of marbling. J. Animal Sci. 17:693.

Robinson, J. R. 1960. Metabolism of intracellular water. Physiol. Rev. 40:112.

Vinogradov, A. P. 1957. The isotope K^{40} and its role in biology. Biokhimiya 22:14. (Cited Kulwich *et al.*, 1960a.)

Woodward, K. T., T. T. Trujillo, R. L. Schuch and E. C. Anderson. 1956. On the correlation of total body potassium with body water. Nature 178:97.

Zobrisky, S. E., H. D. Naumann, A. J. Dyer and E. C. Anderson. 1959. The relationship between the potassium isotope, K^{40} and meatiness of live hogs. J. Animal Sci. 18:1480.

COMPARISON OF 7- AND 10-DAY COLLECTION PERIODS IN DIGESTION AND METABOLISM TRIALS WITH BEEF HEIFERS [1]

DONALD C. CLANTON [2]

Nebraska Agricultural Experiment Station, Lincoln

THE optimum length of the collection periods in digestion and metabolism trials has been a common question in recent years. Most early references, Grindley *et al.* (1915), Hamilton *et al.* (1928), Schneider and Ellenberger (1927), Mitchell and Hamilton (1932), recommend 10- to 14-day collection periods. The results of more recent work tend to contradict this recommendation. Staples and Dinusson (1951), Davis *et al.* (1958), and King *et al.* (1960) found no significant loss in efficiency of determining digestion coefficients when using a 7-day, a 6-day, and a 6-day collection period, respectively, in comparison to a 10-day collection period.

In conducting digestion and metabolism trials, it is important to know the shortest collection time for the desired precision and accuracy. This experiment was conducted to compare a 7-day and a 10-day collection period in digestion and metabolism trials with beef heifers fed rations varying in protein and energy content.

Experimental Procedure

Sixteen bred yearling Hereford heifers were used in four digestion and metabolism trials. They were divided into four equal groups; each group received a different ration. Four heifers, one receiving each ration, constituted a trial. The four trials were run consecutively with a one day break between trials.

Two protein and two energy levels arranged in a factorial design constituted the four rations (table 1). Rations 1 and 3 contained 89% roughage and Rations 2 and 4, 39%. The digestion and metabolism trials were a part of a study of the effect of varying protein and energy intake during the winter on the productivity of bred beef heifers.

The quantity of ration fed to each heifer was based on her body size. The quantity was 11.3 pounds daily for the average size heifer weighing 655 pounds. There were no weighbacks. Water was given free choice. The rations were sampled daily and the samples were composited at the end of each trial, ground and stored for chemical analyses.

The length of preliminary period in this study was not critical because each heifer had been individually fed her respective ration for at least 60 days before the trials. During this time the rations were weighed daily to one ounce accuracy.

A modification of the feces and urine collection apparatus described by Gorski *et al.* (1957) was used to make total collections. The wire frame which separates the feces and urine had a smaller opening to catch the urine flow, thus fitting the body more tightly. The funnel to the bag was more rigidly constructed. Each heifer was kept in a 10 x 10 foot stall with feeder and waterer. Confinement in the individual stalls made it possible to hold the harness and collection bags in place and assure complete collections.

The harness and collection bags were placed on the heifers when they entered the stalls. After this the daily rations were weighed to the nearest gram. The collection period began as soon as the output of urine and feces became quite constant. Generally, this took 4 or 5 days.

After each 24-hour interval during the collection period, the excreta were weighed and sub-sampled. Duplicate samples of feces and urine were taken the first 7 days for the comparison of the 7- and 10-day collection periods. The sub-samples were 5% of the total collection for feces and 1% of the total collection for urine. Both fecal and urine samples were refrigerated during the trial.

At the end of each trial, the 7- and 10-day composites of urine were frozen in tightly capped polyethylene jars. The 7- and 10-day composites of feces were dried at 60° C., in a circulating air oven for 72 hours. Dry matter

[1] Published with the approval of the Director as Paper No. 1113, Journal Series, Nebraska Agricultural Experiment Station.
[2] The author wishes to thank L. A. Swiger for his assistance with the statistical analyses and interpretation.

TABLE 1. THE COMPOSITION OF THE RATIONS FED

Ration no.	1	2	3	4
Dry matter, %	85.54	87.57	85.46	87.30
Organic matter, %	77.57	82.73	77.11	82.13
Crude protein, %	6.19	6.92	9.53	10.19
Ether extract, %	1.62	2.51	1.65	2.21
Crude fiber, %	28.12	13.88	28.35	14.32
Nitrogen-free extract, %	41.32	59.39	37.56	55.34
Gross energy, kcal./lb.	1607.16	1688.88	1616.24	1697.96

was determined on a small sample in an oven at 105° C.

The rations and fecal samples were subjected to proximate analysis and determinations of gross energy. Urine was absorbed on cellulose blocks for determination of its energy content. Energy determinations were made in a Parr bomb adiabatic calorimeter. Methane production was computed from the digestible carbohydrates, using the formula presented by Swift and French (1954).

Results and Discussion

The coefficients of apparent digestibility, metabolizable energy and nitrogen retention are presented in table 2. Correlation coefficients between 7- and 10-day collections were calculated for each nutrient for individual heifers within rations and for the average of the heifers on each ration (table 3).

The correlations between individual heifer's 7- and 10-day collection periods for digestion coefficients, metabolizable energy and nitrogen retention were relatively low (table 3). These correlations indicate that an individual digestibility coefficient computed from 7-day collections will not necessarily agree well with that calculated from a 10-day collection, and gives no indication of how well either is associated with actual digestibility which is the parameter being estimated by both procedures. Most of the correlations agree closely with those reported by King *et al.* (1960).

The high correlations based on the averages of each ration indicate a 7-day collection period is quite accurate for predicting the average of the same heifers for a 10-day collection period (or vice versa) when four heifers are used in the average.

The actual digestibility coefficients of the rations are not known. The variation within rations (table 4) is a measure of how consistent 7- or 10-day collection periods are in estimating the digestibility of the rations. Since the four trials were conducted at different times, the mean square for the interaction between rations and trials was used to compare the efficiency of 7- vs. 10-day collections. This mean square is expected to contain the variance within rations and trials, plus the variation due to the interaction between rations and trials. The make-up of this mean square is of little consequence since the comparison of 7- and 10-day collections was of primary importance. In addition, it seems

TABLE 3. CORRELATION COEFFICIENTS BETWEEN 7- AND 10-DAY COLLECTION PERIODS FOR DIGESTION COEFFICIENTS, METABOLIZABLE ENERGY AND NITROGEN RETENTION

Nutrient	Individual heifers within rations	Average of heifers by rations
Dry matter	0.876	0.992
Crude protein	0.661	0.977
Ether extract	0.298	0.913
Crude fiber	0.734	0.985
Nitrogen-free extract	0.815	0.997
Energy	0.782	0.997
Metabolizable energy	0.787	0.998
Nitrogen retention	0.709	0.963

TABLE 2. AVERAGE APPARENT DIGESTION COEFFICIENTS, METABOLIZABLE ENERGY, AND NITROGEN RETENTION OF RATION

	7-day collection				10-day collection			
Ration no.	1	2	3	4	1	2	3	4
Dry matter	46.1	58.6	50.3	60.6	45.4	56.2	49.6	60.2
Organic matter	50.3	61.1	54.2	63.3	49.3	58.6	52.4	63.5
Crude protein	38.6	44.9	60.1	53.5	36.6	41.8	57.0	54.9
Ether extract	42.5	65.5	31.6	49.8	42.4	54.1	32.4	53.0
Crude fiber	46.3	31.4	49.1	32.0	45.9	27.3	50.3	32.4
Nitrogen-free extract	55.0	69.7	55.7	73.8	53.8	68.1	52.8	73.5
Energy	49.7	61.1	53.2	63.7	49.3	59.5	52.6	63.1
Metabolizable energy, kcal./lb.	672.8	884.2	722.9	925.3	669.4	862.0	712.8	915.9
Nitrogen retention, gm./day	10.4	18.5	24.6	24.2	9.1	16.8	20.7	24.8

TABLE 4. COMPARISON OF MEAN SQUARES OF DIGESTION COEFFICIENTS, METABOLIZABLE ENERGY AND NITROGEN RETENTION FROM 7- AND 10-DAY COLLECTION PERIODS [a]

Nutrient	7-day collection	10-day collection
Dry matter	11.07	10.03
Crude protein	23.96	26.30
Ether extract	137.14	71.55
Crude fiber	31.62	54.19
Nitrogen-free extract	14.20	8.54
Energy	8.22	7.33
Metabolizable energy	1763.00	1764.00
Nitrogen retention	22.66	16.09

[a] Based on the mean square for interaction between trials and rations when a single heifer constituted a trial on each ration.

unlikely that such an interaction would be large, since the rations were similar and the differences in time were rather small. This design is exactly analogous to using the block by treatment interaction as error in a randomized block experiment. The interaction mean square was smaller for the 10-day collection period for all measures except crude protein and crude fiber digestibility. The interaction for metabolizable energy was essentially the same. These findings do not support the findings of King *et al.* (1960), who reported less variation in digestion coefficients calculated from a 6-day collection period than from a 10-day collection period. King's only exception was crude fiber. Staples and Dinusson (1951) reported less variation from 10-day collections when compared to 7-day collections except for dry matter digestibility. Their loss in efficiency from using the 7-day collection period was small. Having additional days in the collection period would be expected to reduce the variation in the composite samples by reducing daily variation. The amount of variation that can be tolerated should govern the length of a collection period. It appears that for the determination of dry matter digestibility, protein digestibility and metabolizable energy, there is little advantage in using longer than a 7-day collection period.

Based on these results the number of animal replications needed to determine digestibility coefficients with a certain accuracy can be estimated. For example, the standard error of a ration mean ($\sqrt{\frac{s^2}{n}}$) for dry matter from the 7-day collection was $\sqrt{\frac{7.05}{4}} = 1.33$. When reducing n, the number of animals, to three, two or one, the standard error of a mean becomes 1.53, 1.88 or 2.66, respectively. As discussed above these mean squares were maximum estimates of the variation of animals on the same ration.

When the digestion coefficients in table 2 were subjected to an analysis of variance, using length of collection time as one variable with one degree of freedom, no significant differences were found between the 7- and 10-day collections. This analysis indicates that 7- and 10-day collections were comparable in measuring digestibility and metabolism.

The interaction between length of collection periods and type of ration was negligible, indicating that the rations were evaluated similarly on either length trial.

Summary

Sixteen individual digestion and metabolism trials, using four heifers and four rations, were conducted to compare 7- and 10-day collection periods. The four rations were two protein and two energy levels arranged in a factorial design. With the exception of curde protein and crude fiber digestibility there was less variation associated with the coefficients calculated from the 10-day collection period. There was no significant difference in the digestion coefficients, metabolizable energy or nitrogen retention determined from the two methods regardless of the type of ration. In this study high correlations based on the averages of each ration, indicate a 7-day collection period is sufficiently accurate for predicting the average of the same heifers on a 10-day collection period when four heifers are used in the average.

Literature Cited

Davis, C. L., J. H. Byers and L. E. Luber. 1958. An evaluation of the chromic oxide method for determining digestibility. J. Dairy Sci. 41:152.

Gorski, J., T. H. Blosser, F. R. Murdock, A. S. Hodgson, B. K. Soni and E. R. Erb. 1957. A urine and feces collecting apparatus for heifers and cows. J. Animal Sci. 16:100.

Grindley, H. S., W. A. Cochel, L. D. Hall and W. A. Carroll. 1915. Methods of experimentation in animal nutrition. Proc. Am. Soc. Animal Prod. pp. 101.

Hamilton, T. S., H. H. Mitchell and W. G. Kammlade. 1928. The digestibility and metabolizable energy of soybean products for sheep. Ill. Agr. Exp. Sta. Bul. 303.

King, W. A., J. Lee, III, H. J. Webb and D. B. Roderick. 1960. Comparison of 6- and 10-day collection periods for digestion trials with dairy heifers. J. Dairy Sci. 43:388.

Mitchell, H. H. and T. S. Hamilton. 1932. The effect of the amount of feed consumed by cattle on the utilization of its energy content. J. Agr. Res. 45:163.

Schneider, B. H. and H. B. Ellenberger. 1927. Apparent digestibility as affected by length of trial and by certain other variations in the rations. Vt. Agr. Exp. Sta. Bul. 270.

Staples, G. E. and W. E. Dinusson. 1951. A comparison of the relative accuracy between seven-day and ten-day collection periods in digestion trials. J. Animal Sci. 10:244.

Swift, R. W. and C. E. French. 1954. Energy Metabolism and Nutrition. The Scarecrow Press. Washington, D. C.

EFFECT OF SEVERAL VARIABLES ON UTILIZATION OF HIGH-ROUGHAGE PELLETS BY LAMBS [1]

D. C. Church, J. A. B. McArthur and C. W. Fox

Oregon Agricultural Experiment Station, Corvallis and Union

A REPORT by Neale (1953) and subsequent reports from other experiment stations on the use of large quantities of roughage in completely pelleted lamb fattening rations have stimulated much interest by lamb feeders and experiment station workers. Although not unanimous, the bulk of research reports have indicated that pelleted rations containing relatively large quantities of roughage (55% or more of the ration have been superior for liveweight gain and feed conversion to similar rations fed unpelleted.

Most of the published literature concerned with the evaluation of pelleted feeds has dealt with ration formulation or studies designed to determine the effect of pelleting *per se* with the result that many variables which might have some effect on utilization of such rations have not been thoroughly investigated. The research reported herein was designed to evaluate the following: pellet size, roughage grind, and percent of hay in pellets.

Experimental Procedure

The same general procedures in handling experimental lambs were used in each trial. Lambs were shorn, drenched twice with phenothiazine, numbered, and allotted to treatment on the basis of body weight. Initial weights were taken to the nearest pound after a feed of legume hay. Periodic weights were taken at approximately weekly or biweekly intervals throughout the trial. Final weights were taken without any restriction of feed or water and dressing percents were calculated on the basis of final feedlot weight and hot carcass weights since chilled carcass weights were not available. After allotting to treatment, lambs were given free access to experimental rations, usually with no prior access to pelleted feeds. Mineralized salt blocks were available to all lots. In the presentation of data, where factorial designs were employed, means are shown for the main treatments only. Data were analyzed by analysis of variance.

[1] Technical Paper No. 1403.

Experiment 1. Effect of Roughage Grind and Pellet Size on Lamb Performance

Trial 1. This trial was set up as a 2 x 2 factorial design with two levels of a feed additive and with the roughage in the pellet ground through either a 5/32 in. or a 9/32 in. hammer mill screen and made up into ⅜ in pellets. The ration contained 40% alfalfa hay, 20% grass hay, 32% ground barley, 2.5% linseed oil meal, 5% molasses, and 0.5% steamed bone meal. This trial involved replications at the central station at Corvallis, and at the Eastern Oregon Branch station at Union, Oregon, with 20 lambs per treatment at each station. Lambs at Union were self-fed for 73 days. At Corvallis, all lambs weighing 100 lb. after 34 days on feed were topped out, the remainder were fed for a total of 57 days. Data are shown in table 1.

Trial 2. White-faced range-bred wether lambs were allotted to treatment in a 3 x 3 x 3 factorial design. The basal ration was formulated as follows: 30% alfalfa hay, 35% mixed grass hay (weathered), 27.5% ground barley, 2% soybean oil meal, 0.5% steamed bone meal, and 5% molasses. The roughage was ground through hammer mill screens of 3/32, 3/16, or ¼ in. and made up into pellets of ¼, ⅜ or ½ in. in size with all combinations of pellet size and hammer mill screen size represented in the experiment (table 1). All lambs were fed for a period of 81 days.

Experiment 2. Effect of Various Percentages of Alfalfa Hay in Pellets

Trial 1. Heavy feeder lambs were allotted to the following pelleted rations: 100% alfalfa; 90% alfalfa, 5% ground barley, 5% molasses; 80% alfalfa, 15% ground barley, 5% molasses; 70% alfalfa, 25% ground barley, 5% molasses; and 70% alfalfa, 25% steam-rolled barley, 5% molasses. All lambs were fed for a period of 49 days at the Union Station.

Trial 2. Heavy feeders with both wethers and ewes represented were fed the following pelleted rations: 100% alfalfa; 85% alfalfa,

TABLE 1. EFFECT OF PELLET SIZE AND ROUGHAGE GRIND ON LAMB PERFOMANCE, EXPERIMENT 1

	Trial 1		Trial 2					
	Screen size		Screen size			Pellet size		
Principal treatment	5/32"	9/32"	3/32"	3/16"	1/4"	1/4"	3/8"	1/2"
Number lambs	40	40	24	24	24	24	24	24
Days on feed	61	63	81	81	81	81	81	81
Initial weight, lb.	70.6	70.0	65.5	66.7	65.8	65.7	65.2	67.1
Final weight, lb.	105.3	105.1	93.3	96.2	95.9	95.9	95.3	94.3
Daily gain, lb.	0.57	0.56	0.34	0.36	0.37	0.37	0.37	0.33
Hot carcass wt., lb.	50.8	50.8	44.4	46.4	46.2	45.6	45.9	45.5
Carcass yield, %	48.2	48.4	47.6	48.2	48.2	47.5	48.2	48.2
Carcass grade[a]	7.7	7.9	5.9	6.6	6.1	6.4	6.1	5.9
Feed/lb. gain, lb.	7.9	7.9	10.4	10.8	11.5	11.7	10.5	10.6

[a] Utility=3, Good=6, Choice=9.

10% ground barley, 5% molasses; 70% alfalfa, 25% ground barley, 5% molasses; 70% alfalfa, 25% steam-rolled barley, 5% molasses; and 65% alfalfa, 30% ground barley, 5% molasses. All lambs were fed individually for a period of 49 days at the Corvallis station. Data are presented in table 2.

Results and Discussion

Experiment 1. Analysis of data from the two trials in this experiment did not indicate any significant response due to differences in the hammer mill screen used to grind the roughage, or due to the size of the pellet used, although trends in lamb performance (Trial 2) indicated an increase in gain as the screen size increased and as the pellet size was reduced. The individual lot which gained the most and had the most efficient feed conversion was one in which the roughage was ground through a 3/16 in. screen and made up into a ½ in. pellet. Gross observations indicated that the larger pellets were more susceptible to crumbling with the result that consumption dropped somewhat and considerably more feed was weighed back. This probably should have been considered wastage. The ration employed in Trial 2 resulted in a low rate of gain for pelleted feeds. This was attributed to the large percentage (35%) of weathered grass hay which was included in the pellet on the assumption that a ration having a large percent of such low-quality roughage should show some difference in response if any true differences exist.

The data from Experiment 1 are in agreement with that of Esplin and Story (1957) who found no differences in lamb response in pellets differing in size. Insofar as roughage grind is concerned, Esplin and Hazle (1958) reported that lambs gained more on a 50-50 alfalfa-corn pellet when the alfalfa was ground through a ¼ in. screen as compared to grinding through a 1/16 in. screen.

TABLE 2. EFFECT OF AMOUNT OF ALFALFA HAY ON LAMB PERFORMANCE, EXPERIMENT 2

	Trial 1					Trial 2				
Lot number	1	2	3	4	5[a]	1	2	3	4[a]	5
% Hay in pellet										
weight, lb.	100	90	80	75	75	100	85	75	75	65
Number lambs	8	8	8	8	9	9	9	9	9	9
Days on feed	49	49	49	49	49	49	49	49	49	49
Initial weight, lb.	94.6	91.0	89.0	85.5	85.7	83.1	86.0	82.7	83.1	85.7
Final weight, lb.	123.1	122.2	120.8	120.1	115.4	105.3	110.7	106.9	110.7	108.7
Daily gain, lb.	0.58	0.64	0.65	0.71	0.61	0.45	0.50	0.49	0.56	0.47
Hot carcass										
weight, lb.	60.8	61.4	59.1	59.5	59.1	54.9	58.2	55.8	57.9	57.9
Carcass yield, %	49.3	50.2	49.0	49.5	51.2	52.1	52.6	52.2	52.3	53.3
Carcass grade[b]	7.1	8.6	7.5	7.9	8.3	9.0	9.0	9.0	9.3	9.0
Feed/lb. gain, lb.	9.0	8.4	8.4	7.4	8.3	9.0	8.9	10.0	9.1	10.0

[a] Steam-rolled barley in these pellets.
[b] Utility=3, Good=6, Choice=9.

Meyer *et al.* (1959) found that lambs gained more when the hay in an all-alfalfa pellet was ground through a 1/16 in. screen and made up into ⅜ in. pellets than when the hay was put through a 1 in. screen and made up into 4 in. wafers. The data of Esplin and Hazle (1958) indicate that alfalfa hay can be ground too finely, but data reported herein indicate that grass hay mixtures can be ground very fine without any detrimental effects.

Experiment 2. Although differences were not statistically significant, the two trials in Experiment 2, (table 2) showed maximum lamb gain when the pellets contained approximately 75% alfalfa hay. Carcass grades in Trial 1 were based on 1959 U.S.D.A. standards, and in Trial 2 on the 1960 revised U.S.D.A. standards. Although lambs in each trial were heavy at the start of the trials, Trial 2 did show that a pellet of 100% alfalfa was sufficient to bring lambs up to the choice grade on a relatively short feeding period (49 days). Lighter lambs carrying less finish may not respond as well on high-roughage pellets (Neale, 1953). Steam-rolled barley did not improve lamb performance significantly over that of ground barley.

Data from Experiment 2 agree in general with those from New Mexico (Neale, 1953, 1955, 1958), and from the Kansas Station (Bell *et al.*, 1955, 1956; Menzies *et al.*, 1960) in that the maximum gain on a variety of pelleted rations has usually been obtained on 65 to 80% roughage pellets. The Kansas data have shown that feed conversion improved as concentrates in the pellet increased, and cost of gain favored the higher roughage pellets. Carcass yields based on feedlot weights increased as the amount of hay in the pellets decreased, and the grades, in general, improved slightly as the amount of concentrate increased.

Published information by other investigators (Hartman *et al.*, 1959; McClure *et al.*, 1960; Perry *et al.*, 1959; Ross and Pavey, 1959) indicates about the same results of increased gains when roughage is increased in a mixed pellet. In general, data have indicated a lower dressing percent on the higher roughage rations and in some cases lower grades, although this is not always the case (Ross and Pavey, 1959). In other comparisons, (Weir *et al.*, 1959) found that 100% alfalfa pellet-fed lambs gained just as well as lambs receiving a pellet with 30% barley, although feed conversion was in favor of the alfalfa-barley pellet.

It should be noted that comparisons of gain between lots of experimental animals fed rations varying widely in the amount of roughage included can sometimes be quite misleading if there is any appreciable difference in fill or in shrink before or after slaughter. When carcass weights are available one simple means of by-passing errors made by differences in fill on final weights is to use an arbitrary figure for calculating an initial carcass weight (unless reliable experimental data are available) and then to calculate carcass gain. The calculated carcass gain can then be converted back to live gain by expressing the performance of experimental rations as a percent of a control lot. When this method of calculating gain is used for the lots in Experiment 2, the gains figured in the normal manner and the calculated gains, in parentheses, are as follow: Trial 1: 0.58 (0.58), 0.64 (0.67), 0.65 (0.62), 0.71 (0.69) and 0.61 (0.68); Trial 2: 0.45 (0.45), 0.50 (0.51), 0.49 (0.49), 0.56 (0.54) and 0.47 (0.51). Although these comparisons do not show any marked differences they tend to illustrate that those lots receiving the most concentrate were undervalued when shrinkage is not considered. Other comparisons (Church, 1961) taken from the literature show more marked differences. Analyses of a wide variety of data taken under varying conditions from the various Oregon experiment stations has indicated that this procedure does not appreciably change the variability of data so calculated, and where rations result in large differences in fill this procedure reduces the variability within treatment groups.

Summary

In two lamb trials no significant differences in lamb response were observed when the hay (alfalfa and grass) in pellets containing 60 to 65% roughage was ground through hammer mill screens varying in size from 3/32 to ¼ inch or when made into pellets varying between ¼ and ½ inch in size. In a second experiment various levels of alfalfa hay (65–100%) in pellets did not significantly influence lamb response, although maximum gain occurred when 75 to 90% roughage was included in the ration. When lambs were graded under the revised U.S.D.A. standards the 100% hay pellet produced

sufficient finish on heavy feeders so that all lambs graded choice.

Literature Cited

Bell, T. D., A. B. Erhart and D. Richardson. 1955. Pelleted rations for fattening lambs. J. Animal Sci. 14:1194. (Abstr.).

Bell, T. D., D. Richardson, R. F. Cox and J. W. Needham. 1956. The relationship of physical balance in the utilization of pelleted and non-pelleted rations for lambs. Kans. Agr. Exp. Sta. Circ. 335:69.

Church, D. C. 1961. High-roughage pellets for fattening lambs. Feedstuffs 33(9)38.

Esplin, A. L. and A. J. Hazle. 1958. Pellet feeding. Colo. Agr. Exp. Sta. Gen. Series Paper 671.

Esplin, A. L. and C. D. Story. 1957. The effect of size of pellet and of some new rations in the feeding of pellets to lambs. Proc. West. Sec. Am. Soc. An. Prod. 8:XXIV.

Hartman, R. H., D. L. Staheli, R. G. Holleman and L. H. Horn. 1959. Effect of stilbestrol and pelleting at two concentrate to roughage rations on the performance and carcass quality of fattening lambs. J. Animal Sci. 18:1114.

McClure, W. H., F. S. McClaugherty, J. P. Fontenot, R. C. Carter and W. M. Mestanza. 1960. Effect of pelleting rations of different concentrate to roughage ratios for fattening lambs. J. Animal Sci. 19:1275. (Abstr.).

Menzies, C. S., D. Richardson, and R. F. Cox. 1960. Concentrate-roughage ratios in pelleted rations for fattening lambs. Kans. Agr. Exp. Sta. Cir. 378.

Meyer, J. H., W. C. Weir, J. B. Dobie and J. L. Hull. 1959. Influence of the method of preparation on the feeding value of alfalfa hay. J. Animal Sci. 18:976.

Neale, P. E. 1953. Alfalfa cubes for fattening lambs and wethers. N. Mex. Agr. Exp. Sta. Bul. 375.

Neale, P. E. 1955. Alfalfa cube mixture for fattening lambs. N. Mex. Agr. Exp. Sta. Bul. 398.

Neale, P. E. 1958. Alfalfa hay pellets for fattening lambs. N. Mex. Agr. Exp. Sta. Bul. 429.

Perry, T. W., W. M. Beeson, M. H. Kennington and C. Harper. 1959. Pelleted complete mixed rations for feeder lambs. J. Animal Sci. 18:1264.

Ross, C. V. and R. L. Pavey. 1959. Effects of pelleting, concentrate: roughage ratios and hexestrol implants on fattening lambs. J. Animal Sci. 18:1510 (Abstr.).

Weir, W. C., J. H. Meyer, W. N. Garrett, G. P. Lofgreen and M. B. Ittner. 1959. Pelleted rations compared to similar rations fed chopped or ground for steers and lambs. J. Animal Sci. 18:805.

BLOAT IN CATTLE. IV. THE ROLE OF BOVINE SALIVA, PLANT MUCILAGES, AND ANIMAL MUCINS [1]

E. E. Bartley and I. S. Yadava

Kansas State University, Manhattan

RECENTLY Van Horn and Bartley (1961) observed that adding saliva to foaming rumen contents increased the rate of release of trapped gas. Adding mucilage from linseed meal also permitted a greater release of gas. It was postulated that reduced salivation during consumption of lush forage that contains foaming compounds may be a factor in bloat etiology and that mucin in saliva may be the foam-breaking and/or foam-inhibiting agent necessary to prevent bloat.

The work reported here was done to furnish more information on the effect of saliva and mucin on frothy legume bloat.

Methods

In Vitro Experiments. The antifoaming activity of bovine saliva, plant mucilages, and animal mucins was tested on saponin foams *in vitro.* Two ml. of a 2% solution of alfalfa saponin [2] in distilled water was added to 20 ml. of distilled water in a clean graduated cylinder. The solution (at 80° F.) was aerated with compressed air flowing through a glass tube with a fine tip for 2 min. at a pressure of 10 mm. water. The tip of the tube was placed 1 in. from the bottom of the cylinder. Foam produced was measured in milliliters as it rose in the cylinder.

The effect of various substances (table 1) on the foam produced by saponin was tested by adding fractions of their solutions to the saponin solution prior to aeration. Bovine saliva used was aspirated from the posterior esophagus, and linseed meal mucilage was prepared by a water extraction method. Both methods were described by Van Horn and Bartley (1961). The saliva was viscous and rich in mucin. Three animal mucin products, designated as animal mucins S, T, and W, were tested. Mucin S [3] is an acid precipitated protein obtained from fresh bones in the production of Swift's Technical Protein Colloids. Mucin S contained 52.7% mucin, 4.9% ash, 1.2% reducing sugars, and 7.1% moisture. Mucin T [3] is a fraction precipitated with alcohol after the hydrochloric acid digestion of hogs' stomach linings. This product contained 64.5% mucin, 5.2% ash, and 5.9% moisture. Mucin W [3] is a crude intestinal mucin collected from intestinal tracts, dried under vacuum at low temperature and powdered by milling. The other products used and their source are shown in table 1.

In Vivo Experiments. Five sets of fistulated identical-twin dry cows were used to test the bloat preventing ability of several plant mucilages and animal mucins. Various quantities of the test materials were introduced through fistulas into rumina approximately 30 min. before pasturing. All animals were

TABLE 1. ANTIFOAMING ACTIVITY OF BOVINE SALIVA, VARIOUS PLANT MUCILAGES, AND ANIMAL MUCINS ON ALFALFA SAPONIN FOAM PRODUCTION

Test substance	Aqueous concentration	Volume added to saponin soln.[a]	Foam produced[b]
	%	ml.	ml.
Control	...	...	90
Arrow root[c]	5.0	1.8	84
Irish moss[c]	2.5	1.0	80
Acacia gum[c]	5.0	0.2	50
Locust bean gum[c]	2.5	1.8	48
Psyllium mucilage[d]	5.0	1.8	40
Linseed mucilage	2.5	4.0	28
Animal mucin-W	5.0	1.8	24
Bovine saliva	undiluted	2.0	5
Animal mucin-T	5.0	1.8	2
Animal mucin-S	5.0	1.8	0

[a] Only most effective concentration shown.
[b] Average of three trials. LSD ($P<.05$)=24.5.
[c] Natural products rich in mucilage. Through the courtesy of American Cyanamid Co., Pearl River, N. Y.
[d] Mucilage extracted from psyllium seed. Through the courtesy of G. D. Searle and Co., Chicago, Ill.

[1] Contribution No. 295, Department of Dairy Husbandry, Kansas Agricultural Experiment Station, Manhattan. Supported in part by grants from Swift and Co., Chicago, Ill., and the American Cyanamid Co., Pearl River, N. Y. The assistance of H. C. Fryer, Department of Statistics, Kansas State University, is gratefully acknowledged.

[2] Through the courtesy of G. O. Kohler, Western Utilization Research and Development Division, Agricultural Research Service, U.S.D.A., Albany, Calif.

[3] S, T, and W through the courtesy of Swift and Co., Chicago, Ill.; Thompson-Hayward Chemical Co., Kansas City, Mo.; and Wilson and Co., Chicago, Ill.

TABLE 2. SCALE USED IN RATING FROTHY BLOAT IN FISTULATED ANIMALS

Score	Degree of frothing	Degree of abnormal distention		Other abnormalities
		Left side	Right side	
0	None	None	None	None
1	Slight	None	None	None
2	Definite	None	None	None
3	Frothy rumen ingesta gushes out several feet when fistula cap is removed[a]	Slight to moderate	None	None
4	Ditto	Definite, drumlike	Slight	Restless
5	Ditto	Badly distended, left hip hidden, skin tight	Badly distended	Defecation, urination, muscular incoordination, protruding anus, respiratory distress

[a] When animals were in this condition, care was taken to allow no more than a few liters of foam to escape since evacuation of a major portion of rumen contents would disturb rumen function and curtail bloat.

pastured on good quality alfalfa pasture (usually in an early stage of growth). The cows were turned into pasture early in the morning and remained on pasture for approximately 6 hr. When the cows were removed from pasture, they were kept in drylot with only fresh water and salt available. Cows were not permitted water during grazing periods except on very hot days.

Fistulated animals are useful in bloat studies because they permit observation of the development of rumen foam. However, the occasional removal of the cap closing the fistula plug precludes the use of the scale used for scoring bloat in intact animals. A scale (table 2) was developed to permit evaluation of foam formation and also coincide as much as possible in degree of bloating with the scale proposed by Johnson *et al.* (1958) for scoring bloat in intact animals. The twins were scored at intervals of approximately 2 hr.

Results

Aeration of the saponin solution produced a large volume of stable foam (table 1). The addition of bovine saliva and two sources of animal mucin (T and S) to the saponin solution effectively prevented the formation of stable foam (table 1).

The solution of mucin S had a pH of 6.4. No change in antifoaming activity was observed when the pH was changed to 7.7 with sodium bicarbonate. Similarly the antifoaming activity was not altered on heating the mucin solution to 110° F. or to 200° F. (data not shown).

Animal mucin (W) and mucilage extracted from linseed meal had some antifoaming activity (table 1) but less than that of saliva or mucins T and S. Psyllium seed and the other plant mucilages were found not to be efficient antifoaming agents. The foam inhibiting effects of saliva and linseed meal mucilage are shown in figure 1.

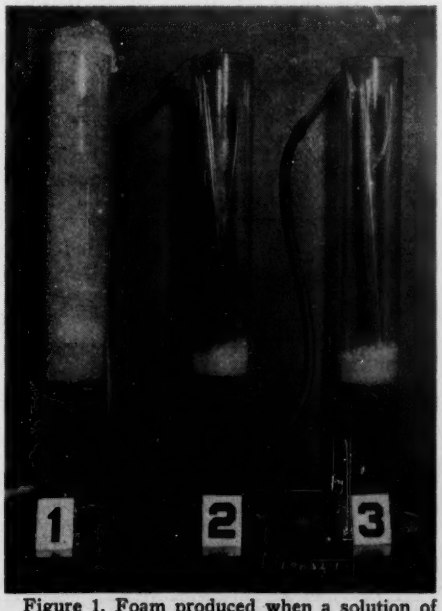


Figure 1. Foam produced when a solution of alfalfa saponin is aerated (1). Foam inhibiting effects of bovine saliva (2) and linseed meal mucilage (3) when added to alfalfa saponin solution.

TABLE 3. EFFECT OF 50 GM. MUCIN T ON THE DEGREE OF BLOAT IN IDENTICAL TWIN COWS GRAZING ALFALFA

Trial I (7 days)						
Treatment	Control			50 gm. mucin T/cow/day		
Twin no.	A_1	B_1	C_2	A_2	B_2	C_1
Bloat index						
2 hr.	3.4	1.7	2.4	0.4	0	0
4 hr.	2.1	1.4	2.7	0.6	0.6	0.9
6 hr.	1.9	1.7	2.9	2.1	1.0	1.9

Trial II (7 days)						
Treatment	Control			50 gm. mucin T/cow/day		
Twin no.	A_2	B_2	C_1	A_1	B_1	C_2
Bloat index						
2 hr.	3.7	1.1	2.0	0	0	0
4 hr.	2.9	1.7	1.6	1.9	0.4	0.4
6 hr.	3.3	2.0	1.3	1.6	0.3	0.9

On the basis of these *in vitro* results several of the above materials were tested on alfalfa bloat *in vivo*. Preliminary testing of the plant mucilages showed that they were not effective bloat preventives (data not shown). Studies with linseed meal were reported elsewhere (Bartley, 1957). Feeding linseed meal to cows before pasturing appeared to reduce the incidence of bloat. Due to the difficulty of extracting mucilage from linseed meal, studies on the bloat preventive action of linseed meal mucilage were abandoned.

Work reported here pertains to the bloat preventing action of the two animal mucins (T and S) which were found to inhibit effectively the formation of alfalfa saponin foam *in vitro*.

It is apparent (tables 3 and 4) that either 50 or 75 gm. mucin T effectively prevented bloat. Though a statistical analysis (t-test of the mean difference between control and mucin scores of twin pairs) indicates that the bloat index of the mucin treated animals is significantly different from those of the controls at 6 hr. (table 5), it is apparent from the data presented in tables 3 and 4 that the bloat preventing effect of mucin decreased at 4 hr. and decreased further at 6 hr. In fact, the bloat preventing effect is not great at 6 hr. and cannot be considered important from a practical standpoint. However, it can be concluded that 50 or 75 gm. of mucin T effectively prevented bloat for at least 4 hr.

Seventy-five gm. of mucin S appeared to be as effective in preventing bloat as 75

TABLE 4. EFFECT OF 75 GM. MUCIN T OR S ON THE DEGREE OF BLOAT IN IDENTICAL TWIN COWS GRAZING ALFALFA

Trial III (6 days)								
Treatment	Control		75 gm. mucin T		Control		75 gm. mucin S	
Twin no.	A_2	D_2	A_1	D_1	E_1	C_1	E_2	C_2
Bloat index								
2 hr.	3.3	3.2	0.5	0.8	1.8	3.2	0.5	0.5
4 hr.	2.7	2.0	0.5	0.3	2.0	2.3	1.3	1.5
6 hr.	3.5	3.5	1.5	0.7	2.0	2.7	1.3	1.3

Trial IV (6 days)								
Treatment	Control		75 gm. mucin T		Control		75 gm. mucin S	
Twin no.	A_1	D_1	A_2	D_2	E_2	C_2	E_1	C_1
Bloat index								
2 hr.	1.7	0.5	0	0	1.5	0.7	0	1.5
4 hr.	1.8	1.0	0.3	0	2.0	0.5	1.0	0.5
6 hr.	2.0	0.5	0	0	1.7	0.8	0.5	1.2

Trial V (6 days)								
Treatment	Control		75 gm. mucin T		Control		75 gm. mucin S	
Twin no.	E_2	C_2	E_1	C_1	A_2	D_1	A_1	D_2
Bloat index								
2 hr.	0.7	0.7	0	0	3.0	0	0.3	0
4 hr.	1.0	1.0	0.5	0	2.2	1.3	0.5	0.8
6 hr.	0.8	1.0	0.8	0	2.2	1.5	1.5	1.5

TABLE 5. STATISTICAL SIGNIFICANCE OF MEAN DIFFERENCE BETWEEN BLOAT INDEXES OF TREATED AND CONTROL ANIMALS

Treatment	Mucin T, 50 gm.	Mucin T, 75 gm.	Mucin S, 75 gm.
Bloat index			
2 hr.	2.3**	1.5*	1.1
4 hr.	1.3**	1.3**	0.8*
6 hr.	0.9*	1.4*	0.6ª

* $P<.05$.
** $P<.01$.
ª $P\sim.09$.

gm. of mucin T at 2 hr. (table 4). However, due to a large error variance caused by a high bloat score for cow 87 in trial IV, the difference was not statistically significant (tables 4 and 5). The bloat preventing effect of 75 gm. mucin S was not so persistent as that of 75 gm. mucin T (tables 4 and 5).

The bloat preventing effect of mucin S was extended (table 6) by increasing the level used from 75 to 300 gm. (too few cases for statistical analysis).

Discussion

Animal mucin products appear to have promise as practical bloat preventives. However, unless their protective action can be extended without greatly increasing the dose, they cannot be recommended for field application. Studies attempting to extend the protective action of mucin are currently in progress. Cellulose cubes were impregnated with mucin with the thought that mucin would float on the rumen ingesta and thereby remain in the rumen longer. Preliminary results indicate that mucin-cellulose cubes are less effective than dry mucin in preventing bloat. It appears that a minimum quantity of mucin should be in intimate association with the rumen ingesta for maximum antifoaming action. This conjecture is congruent with a recent observation made here that mucin added to the rumen directly through the fistula appears to be more effective in preventing bloat than when fed to cows as a portion of the grain-concentrate ration. Similarly, the successes obtained in controlling bloat in some experiments (Reid, 1958) with soybean oil when sprayed on legume pastures and its failure in others when fed mixed in the grain (Reid and Johns, 1957; Elam and Davis, 1959) may be explained on the basis that the grain absorbs the oil and perhaps does not permit maximum antifoaming action in the rumen. Data presented by Johnson *et al.* (1958) indicate effective control of bloat by feeding soybean oil mixed with grain but somewhat greater degree of effectiveness when sprinkled over soilage. It is apparent that the method of administering products to be tested for bloat control will have considerable bearing on the results.

TABLE 6. EFFECT OF 300 GM. MUCIN S ON THE DEGREE OF BLOAT IN IDENTICAL TWIN COWS GRAZING ALFALFA

	Trial VI (6 days)			
Treatment	Control		300 gm. mucin S	
Twin no.	A_2	C_1	A_1	C_2
Bloat index				
2 hr.	1.6	2.4	0	0
4 hr.	2.2	2.0	0	0
6 hr.	2.0	2.2	0.2	0.6

While it is obvious that more work is needed before mucin can be endorsed for field use, it is apparent that salivary mucin can function as an antifoaming agent. The following conditions seem to be necessary for frothy bloat to occur: consumption of plants containing active foaming agents, conditions in the rumen suitable for stable-foam formation, gas production, and finally the lack of sufficient quantities of the antifoaming factor mucin due to reduced salivation on succulent forage.

In support of the hypothesis that saliva plays a beneficial role in bloat, Mendel and Boda (1960) observed that nonbloaters secrete greater quantities of saliva than do bloaters. Also it has been shown that fibrous feeds such as hay stimulate four to five times as much saliva per unit weight of feed consumed as do less fibrous feeds such as fresh grass (Balch, 1958; Bailey, 1959).

Atropine sulfate injected subcutaneously (50 mg. per cow per day) to reduce saliva production increased rumen foam in members of identical twins grazing a mature alfalfa pasture (Yadava, 1960).

Weiss (1953) believed that the formation of rumen foam depends on the consistency of ruminal ingesta which, in turn, is influenced by reflex salivary secretion. Bloat caused by foaming of thick, viscid, ruminal ingesta occurred immediately after succulent, leafy alfalfa was fed. When mature, stalky alfalfa was fed, the ruminal ingesta reverted to a watery consistency and bloat ceased. The action of saliva was apparently ascribed to its diluting effect. The explanation for the bloat protective action of hay was based on

stimulation of salivary flow rather than to lack of stimulation of eructation as suggested by Cole *et al.* (1942).

Johns *et al.* (1958) criticized Weiss' hypothesis concerning the protective role of saliva on the basis that a lack of liquid is not necessary for the production of bloat since several workers had produced bloat with legume juice. Johns' criticism is not valid in the light of results reported here which ascribe an antifoaming effect to saliva rather than a diluting effect. Also, according to Johns (1958), the role of saliva is not as Weiss has suggested because Ferguson and Terry (1955) found that adding extra saliva to animals being dosed with alfalfa juice did not prevent bloat. Ferguson and Terry used synthetic saliva containing no mucin. In one instance they gave 750 ml. of cow's saliva (collected after injection with pilocarpine) to one sheep which received 2.5 liters alfalfa juice. Van Horn (1959) observed that 6 liters of bovine saliva aspirated from the posterior esophagus reduced foaming in one cow feeding on alfalfa pasture but considered this to be a small quanity to add. An average cow on a hay ration secretes approximately 84 liters of saliva per day (calculated from Bailey, 1959).

Several workers (Johns *et al.*, 1958; Phillipson and Reid, 1958; Mangan, 1959) have attributed the role of saliva in bloat to one of promoting foaming. This is based on the fact that salivary proteins are foaming agents and that the aeration of mixed bovine saliva produces a stable foam (Mangan, 1959). However, results of work reported here and previously (Van Horn and Bartley, 1961) suggest that saliva serves as a foam-inhibiting and foam-breaking agent when associated with the foam forming constituents of bloat provoking legumes.

The postulation that bloat results when feeds containing foaming constituents fail to induce sufficient salivary secretion explains why cows may bloat on young succulent legumes while they are not so prone to bloat on more mature legumes or hay. Also, damp or wet legumes are more bloat provoking than the same plants on a dry day possibly because of reduced salivary flow. Young succulent grasses usually do not provoke bloat even though they do not induce a large salivary secretion because they lack the chemical components which augment foaming. Occasionally bloat is reported when cattle graze very succulent immature grasses. Such grasses usually contain a large quantity of foam forming proteins (Ferguson and Terry, 1955). A logical explanation for hereditary differences among animals in their susceptibility to bloat is provided by the knowledge that differences in rate, amount, and kind of salivary secretion exist among animals (Lyttleton, 1960; Mendel and Boda, 1960).

Summary

The antifoaming activity of bovine saliva, plant mucilages, and animal mucins was tested on alfalfa saponin foams *in vitro*. Bovine saliva and two animal mucins effectively inhibited foam formation. Five sets of fistulated identical-twin cows were used to test the bloat preventing ability of several plant mucilages and animal mucins placed in the rumen before pasturing alfalfa. The two animal mucins effective *in vitro* were effective *in vivo* also. Levels of 50 or 75 gm. effectively prevented bloat for at least 4 hours. The role of saliva and mucin in bloat is discussed. It is postulated that bloat results when feeds containing foaming constituents fail to induce sufficient salivary secretion. Mucin appears to serve as a foam-inhibiting and foam-breaking agent.

Literature Cited

Bailey, C. B. 1959. The rate of secretion of mixed saliva in the cow. Proc. Nutrition Soc. 19:xiii.

Balch, C. C. 1958. Observations on the act of eating in cattle. Brit. J. Nutrition 12:330.

Bartley, E. E. 1957. Effectiveness of mucin in reducing the incidence and severity of bloat in cattle. J. Animal Sci. 16:1084 (Abstr.).

Cole, H. H., S. W. Mead and M. Klieber. 1942. Bloat in cattle. California Agr. Expt. Sta. Bull. 662.

Elam, C. J. and Davis, R. E. 1959. Effects of two levels of soybean oil mixed into a complete pelleted steer ration on the incidence of feedlot bloat. J. Animal Sci. 18:1510.

Ferguson, W. S. and R. A. Terry. 1955. Bloat investigations. J. Agr. Sci. 46:257.

Johns, A. T., J. L. Mangan and C. S. W. Reid. 1958. Animal factors in the aetiology of bloat. Proc. New Zealand Soc. Animal Production 19:21.

Johnson, R. H., L. R. Brown, N. L. Jacobson and P. G. Homeyer. 1958. Effectiveness and practicability of some oils, penicillin, n-decyl alcohol, and lecithin in the control of alfalfa bloat. J. Animal Sci. 17:893.

Lyttleton, J. W. 1960. Bloat in cattle. XVIII. The proteins of bovine saliva. New Zealand J. Agr. Res. 3:63.

Mangan, J. L. 1959. Bloat in cattle. XI. The foaming properties of proteins, saponins, and rumen liquor. New Zealand J. Agr. Res. 2:47.

Mendel, V. E. and J. M. Boda. 1960. Physiological studies of the rumen, with emphasis on the animal factors associated with bloat. J. Dairy Sci. 43:873. (Abstr.).

Phillipson, A. T. and C. S. W. Reid. 1958. Distension of the rumen and salivary secretion. Nature 181: 1722.

Reid, C. S. W. 1958. Bloat in cattle. VIII. Prevention by pasture spraying with antifoaming agents. Preliminary experiments with non-lactating dairy cows and sheep. New Zealand J. Agr. Res. 1:349.

Reid, C. S. W. and A. T. Johns. 1957. Bloat in cattle on red clover. III. Treatment and prevention with anti-foaming agents. New Zealand J. Sci. Technol., Sec. A 38:908.

Van Horn, H. H. Jr. 1959. The role of saliva in the etiology and prevention of bloat. M.S. Thesis. Kansas State University, Manhattan, Kans.

Van Horn, H. H. Jr. and E. E. Bartley. 1961. Bloat in cattle. I. Effect of bovine saliva and plant mucin on frothing rumen contents in alfalfa bloat. J. Animal Sci. 20:85.

Weiss, K. E. 1953. The significance of reflex salivation in relation to froth formation and acute bloat in ruminants. Onderstepoort J. Vet. Res. 26:241.

Yadava, I. S. 1960. Effect of bovine saliva, mucin, and several antifoaming agents on alfalfa saponin foams associated with bloat. M.S. Thesis. Kansas State University, Manhattan, Kans.

BLOAT IN CATTLE. V. THE ROLE OF RUMEN MUCINOLYTIC BACTERIA[1]

L. R. FINA,[2] C. A. HAY,[2] E. E. BARTLEY[3] AND B. MISHRA[3]

Kansas State University, Manhattan

THE role of mucin as a bloat preventive has been reported by Bartley and Yadava (1961). They established that animal mucins introduced into the rumen of cattle grazing alfalfa prevents bloat for as long as 4 hours. The reason the effect lasted no longer was unexplained. Recent research has indicated a relationship between rumen microflora and bloat (Bartley *et al.*, 1961; Gutierrez *et al.*, 1958, 1959; Hungate *et al.*, 1955; Jacobson and Lindahl, 1955). That certain antibiotics can control bloat also indicates a possible bacterial role in this syndrome (Barrentine *et al.*, 1956; Brown *et al.*, 1958). Just how bacteria and mucin could be linked as factors in the bloat syndrome, however, is not clear.

Bacteria capable of degrading mucin exist in nature (Bergamini, 1956; Formal and Lowenthal, 1956; Lowenthal and Berman, 1959; Williams and Powlen, 1959). Consequently the short duration of the effectiveness of mucin in preventing bloat might be attributed to destruction by mucinolytic bacteria in the rumen flora. This investigation concerns itself with, (1) a search for rumen mucinolytic bacteria, and (2) attempts to determine relationships between bacterial degradation of salivary mucin and the bloat syndrome.

Experimental Procedure

Bovine saliva collected from the posterior esophagus as described by Van Horn and Bartley (1961), was used as a source of mucin. It was Seitz filtered to remove bacteria.

Bacteria used in this study were isolated as follows: A medium consisting of 20 ml. of saliva plus 30 ml. modified (Harris, 1954) Ashby's mineral salts solution (AMS) was inoculated with 1 ml. of rumen fluid obtained from a bloating fistulated cow. After 24–48 hr. incubation at 37° C., this enriched material was streaked for isolation of pure cultures on nutrient agar and Lord's (1959) carbon-free agar medium containing 30–50 percent Seitz-filtered saliva. After isolation, pure cultures were carried on nutrient agar slants.

Mucinolytic activity of the bacteria isolated was followed by determining the amounts of combined and free sialic acid in saliva to which the microbes had been added. Cultures were washed from slants, suspended and rewashed in AMS, and finally dispensed as a heavy suspension in 10 ml. amounts. An equal volume of fresh saliva (collected from the mouth of a cow after subcutaneous injection of carbachol) was added to these suspensions and the whole was incubated 56 hr. at 37° C. in order to enrich the culture further. Ten ml. of this enrichment was then inoculated into 90 ml. of fresh nonsterile oral saliva. Nonsterile saliva was used so there would be no physical alteration or denaturing of the mucin. Additional uninoculated, nonsterile saliva was used for controls.

As sialic acid, also referred to as neuraminic acid (Bettelheim-Jevons, 1958) combined with protein (mucoprotein) is a constituent of bovine saliva (Gottschalk and Graham, 1959), assay for relative amounts of total and free sialic acid at regular intervals indicated mucinase activity (Aminoff, 1959). The "direct" Ehrlich method of Whitehouse and Zilliken (1960) was used to determine total or combined sialic acid and the "pyrrole" test tube method (Aminoff, 1959), to follow release of free sialic acid. The quantity of each measured colorimetrically was determined in a Bausch and Lomb spectrophotometer. Determinations read as percentage transmission, were comparative, not quantitative. Lower transmission values indicated greater concentrations of total or free sialic acid.

To learn if the isolated mucinolytic organisms were bloat provoking, they were introduced into the rumen of fistulated cows. Five animals were used: Jersey 88, Holstein identical twins 15–16, and Guernsey identical

[1] Contribution No. 371, Department of Bacteriology and No. 298, Department of Dairy Husbandry, Kansas Agricultural Experiment Station, Manhattan. Supported in part by funds provided by North Central Regional Project NC-27 on The Chemistry and Physiology of Bloat.

[2] Department of Bacteriology.

[3] Department of Dairy Husbandry.

twins 22–23. The animals were pastured on mature nonbloat provoking alfalfa. One member of each twin pair and 88 were inoculated with test bacteria. Single pure cultures or a mixture of isolated organisms grown in 400, 800, 1200, 3000, 4000 ml. quantities of nutrient broth were introduced into the rumen. Sterile nutrient broth in the same quantities was given to the control animals. Bloat was scored using a 0–5 scale (Bartley and Yadava, 1961). Observations were made between 0.5 and 3.0 hr. after pasturing.

A similar study was conducted to determine if mucinolytic bacteria could provoke feedlot bloat. Three sets of fistulated identical-twin cows (A_1–A_2 (Jersey), B_1–B_2 (Brown Swiss), C_1–C_2 (Guernsey)) weighing 800–1000 lb. were fed daily 14 lb. of bloat-producing ration (10 lb. ground corn, 2 lb. dehydrated alfalfa pellets, 2 lb. soybean oil meal). After frothy bloat developed, the minimum amount of coarse, long alfalfa hay needed to prevent bloat was determined. Two pounds of hay fed twice daily almost completely prevented frothy bloat. After bloat ceased one of the isolated organisms was grown in 4 liters of nutrient broth for 36 hr., centrifuged, resuspended in 1 liter of 0.85% saline, and introduced into the rumen of one member of each twin pair. After inoculation the animals were observed for symptoms of bloat at periodic intervals.

Results

Four pure cultures of gram negative and one of gram positive nonspore forming rods designated D, E, F, H, and J were isolated. Organism H was gram positive. These new isolates have not been completely characterized or identified. Some of their characteristics are recorded in table 1.

The mucinase activity of the organisms is recorded in table 2. To follow the enzymatic breakdown of total sialic acid by test organism J, data indicating its activity and that of uninoculated saliva were plotted together. Organism J degraded total sialic acid far more rapidly than did contaminating organisms in the nonsterile control saliva (figure 1). This general picture is also observed for organisms D, E, F, and H when plotted graphically.

When the organisms isolated above were placed in the rumen of fistulated cows grazing a nonbloat provoking pasture late in the summer, bloat was more severe in inoculated animals than in controls in 10 of 16 trials (data not shown). Bloat started within 0.5 to 3.0 hr. after pasturing (animals were inoculated immediately before being pastured). Organisms F and J in single pure cultures and a mixture of DEFHJ produced bloat in varying degrees greater than in controls. One of the cows, 88, previously not susceptible to bloat, bloated severely when inoculated with organism F. Bloat in this animal persisted for 7 days. After bloat finally ceased, reinoculation with a mixture of DEFHJ caused it to recur.

These preliminary experiments were repeated (table 3) to see if mucinolytic bacteria could provoke feedlot bloat. Organism H was chosen because it was a mucinase producer.

TABLE 1. PRELIMINARY CHARACTERIZATION OF ISOLATED MUCINOLYTIC BACTERIA

Organism	Motility	Appearance on nutrient agar slant	Action on litmus milk	Indole	H_2S	Gelatinase	Glucose[a]	Sucrose[a]
D	Neg.	Yellowish white, viscid translucent colonies	Proteolysis in 8 days	Neg.	Neg.	Neg.	NC	NC
E	Pos.	Slight yellow tint to colonies	Proteolysis in 6 days	Neg.	Neg.	Neg.	NC	A
F	Pos.	Greenish white mucoid colonies, medium became green	Proteolysis in 2 days	Neg.	Neg.	Pos.	AG	AG
H	Neg.	Grayish white translucent colonies	Acid coagulation reduction	Neg.	Pos.	Pos.	AG	AG
J	Pos.	White, opaque, viscid colonies	Acid curd, proteolysis slight in 6 days	Neg.	Neg.	Neg.	AG	AG

[a] NC=no change in media, A=acid production, G=gas production.

TABLE 2. DEGREE OF MUCINASE ACTIVITY OF ISOLATED ORGANISMS [a]

Time, hours	Organism inoculated					
	D	E	F	H	J	Control
Total Sialic Acid (Percent transmission at wave length 565 mu.)						
0	23	21	21	22	21	21
4	25	22	21	23	22	24
8	25	26	24	24	29	21
12	78	59	23	36	78	21
14	82	78	28	74	86	27
16	76	80	45	73	84	26
18	92	91	77	82	86	37
24	86	87	78	84	89	81
36	89	92	76	85	91	86
Free Sialic Acid (Percent transmission at wave length 560 mu.)						
0	80	94	87	84	86	90
4	91	84	96	89	88	99
8	80	86	93	81	75	90
12	100	93	80	67	87	93
14	93	98	58	99	90	88
18	96	94	98	90	91	78
24	98	97	97	96	89	94
36	93	92	89	90	97	94

[a] Action of these organisms was on oral saliva.

Also, it was catalase negative and appeared from the litmus milk reaction to be more typically a lactic acid-producing type. In Experiment I definite bloat occurred in all treated animals within 12 to 24 hr. after inoculation, while no change occurred in the degree of bloat in the control animals. In Experiment II the quantity of hay fed did not completely prevent bloat in two control animals (A_2 and B_2). However, after inoculation the treated animals bloated more severely than their twin controls. Following Experiment II, bloat was stopped in all animals by feeding them long alfalfa hay as the sole diet for one week. After bloat ceased, the feedlot bloat ration again was fed along with 4 lb. of long hay for another week before inoculating the test animals. Experiment III was conducted by reversing test and control animals used in Experiments I and II. Again in every instance the inoculated animals bloated the day following inoculation and continued to bloat for 8 days (duration of the experiment), while bloat in control animals was insignificant.

Discussion

Data presented in this paper demonstrate that mucinolytic bacteria can be isolated from the bovine rumen and that these organisms can destroy mucoprotein quite rap-

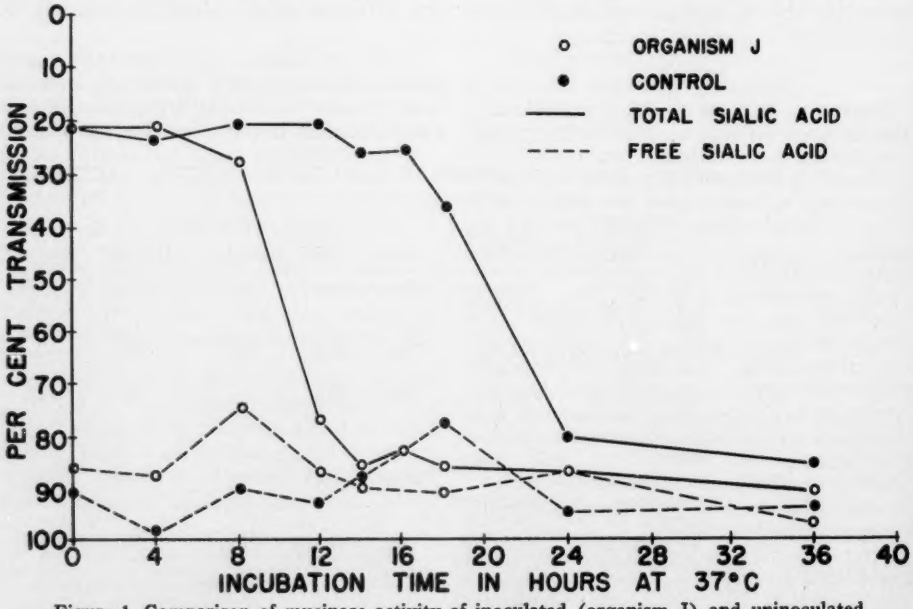


Figure 1. Comparison of mucinase activity of inoculated (organism J) and uninoculated nonsterile saliva (control).

TABLE 3. FEEDLOT BLOAT FOLLOWING INOCULATION WITH MUCINOLYTIC RUMEN ORGANISM H

Twin pairs	Treatment	Maximum bloat index[a]					
		Date before inoculation	Dates after inoculation				
		12–24–60	12–25	12–26	12–27	12–28	12–29
		Experiment I					
A1	Inoculated	0	4	3	3	2	2
A2	Control	0	0	0	0	0	0
B1	Inoculated	2	4	4	4	3	2
B2	Control	2	2	2	2	0	0
C2	Inoculated	0	3	3	2	0	0
C1	Control	0	0	0	0	0	0
		Experiment II					
		1–15–61	1–16	1–17	1–18	1–19	1–20
A1	Inoculated	0	4	3	3	3	3
A2	Control	2	2	2	3	3	2
B1	Inoculated	0	3	3	4	4	4
B2	Control	2	3	3	2	2	2
C2	Inoculated	0	3	3	3	3	3
C1	Control	0	0	0	0	0	0
		Experiment III					
		2–3–61	2–4	2–5	2–6	2–7	2–8	2–9	2–10	2–11
A2	Inoculated	0	4	4	4	3	4	4	3	3
A1	Control	1	1	0	0	0	2	1	1	1
B2	Inoculated	1	4	4	4	3	3	3	3	3
B1	Control	0	0	0	0	0	1	1	1	1
C1	Inoculated	0	2	2	2	2	3	3	3	2
C2	Control	0	0	0	0	0	0	0	0	1

[a] Maximum bloat index observed during the day based on rating from O (no bloat) to 5 (severe bloat).

idly (figure 1). However, there is an initial lag of 8 hr., perhaps until inoculated organisms develop an effective concentration, before mucoprotein destruction occurs. In the uninoculated saliva it was over 16 hr. before the normal mucinolytic flora of the saliva became effective. It is apparent from these studies that uninoculated saliva or salivary mucin remains relatively stable. Presumably breakdown occurs when a sufficient concentration of mucinolytic bacteria become established.

From results of earlier studies conducted at the Kansas station (Van Horn and Bartley, 1961; Bartley and Yadava, 1961) it was postulated that reduced salivation during consumption of lush forage that contains foaming compounds may be a factor in bloat etiology and that mucin in saliva may be the antifoaming agent necessary to prevent bloat. In both the alfalfa pasture and feedlot bloat studies reported here conditions that can produce stable rumen foam were found. Also it has been shown that fibrous feeds, such as hay, stimulate production of four to five times as much saliva per unit weight of feed consumed as do less fibrous feeds, such as fresh grass or ground and pelleted feeds (Balch, 1958; Bailey, 1959). Hence it is hypothesized that the absence of bloat in cows fed mature alfalfa pasturage or the feed-lot bloat ration with hay was due to protection afforded by increased salivary flow stimulated by the mature pasture or hay. That the relief of bloat was overcome by inoculating the rumina with mucinolytic organism H can be ascribed to the mucinase activity of the added bacteria which destroyed salivary mucin so the saliva became ineffective as an antifoaming agent. A lowered rumen mucin content due to reduced salivation during consumption of feeds containing foaming compounds may trigger bloat even without bacterial action. Existence of mucinase producers in the rumen would further tip the balance in favor of bloat.

Studies are presently being conducted to determine if other mucinolytic bacteria, not of rumen or bovine origin, can provoke bloat.

In addition the action of antibiotics on the organisms isolated and discussed is being investigated, as are identification of isolates and the enzymatic destruction of mucin.

Summary

A number of organisms were isolated from the rumen and tested for mucinolytic activity. Five which were capable of breaking down salivary mucin and utilizing free sialic (neuraminic) acid were found. When cultures of these organisms were introduced into the rumina of fistulated cows grazing a mature nonbloat provoking alfalfa pasture, bloat resulted in the majority of instances.

Three sets of fistulated identical-twin cows were fed a bloat-producing ration. After frothy bloat developed the minimum amount of coarse, long hay needed to prevent bloat was determined. When bloat ceased, one member of each twin pair was inoculated with a mucinolytic rumen organism. This resulted in a marked increase in the degree of bloat over the uninoculated controls.

It was previously shown at this station that bloat foam could be inhibited or dispersed by salivary mucin. Thus, it was proposed that bloat may occur when mucin concentration in the rumen is lowered because of decreased salivation on feeds containing foaming constituents. It is now proposed that the concentration of mucin necessary to prevent bloat can be further reduced by the destructive action of mucinolytic microorganisms.

Literature Cited

Aminoff, D. 1959. The determination of free sialic acid in the presence of the bound compound. Virology 7:355.

Bailey, C. B. 1959. The rate of secretion of mixed saliva in the cow. Proc. Nutrition Soc. 19:xiii.

Balch, C. C. 1958. Observations on the act of eating in cattle. Brit. J. Nutr. 12:330.

Barrentine, B. F., C. B. Shawver and L. W. Williams. 1956. Antibiotics for prevention of bloat in cattle grazing ladino clover. J. Animal Sci. 15:440.

Bartley, E. E., T. J. Claydon, L. R. Fina, C. A. Hay and I. S. Yadava. 1961. Bloat in Cattle II. Its development on alfalfa pasture after inoculation of empty rumina with autoclaved or fresh rumen fluid. J. Dairy Sci. 44:553.

Bartley, E. E. and I. S. Yadava. 1961. Bloat in cattle, IV. The role of bovine saliva, plant mucilages, and animal mucins. J. Animal Sci. 20:648.

Bergamini, L. 1956. Mucin splitting enzymes among microorganisms. Zentralblatt Bakteriol. Parasitenk. Abt. I. 165:122.

Bettelheim-Jevons, F. R. 1958. Protein-carbohydrate complexes. Adv. Protein Chem. 13:35.

Brown, L. R., R. H. Johnson, N. L. Jacobson and P. G. Homeyer. 1958. Effects of administration of oils and of penicillin on incidence and severity of bloat and certain other responses of cattle. J. Animal Sci. 17:374.

Formal, S. B. and J. P. Lowenthal. 1956. Distribution of mucinolytic activity in strains of Shigella. Proc. Soc. Exp. Biol. Med. 92:10.

Gottschalk, A. and E. R. B. Graham. 1959. 6-a-D-sialyl-N-acetylgalactosamine: the neuraminidase-susceptible prosthetic group of bovine salivary mucoprotein. Biochem. et Biophys. Acta. 34:380.

Gutierrez, J., R. E. Davis and I. L. Lindahl. 1958. Dissimilation of alfalfa saponins by rumen bacteria. Science 127:335.

Gutierrez, J., R. E. Davis and I. L. Lindahl. 1959. Bacterial changes in the rumen during the onset of feed-lot bloat of cattle and characteristics of *Peptostreptococcus elsdenii* n. sp. Appl. Microbiol. 7:16.

Harris, J. O. 1954. The influence of carbon dioxide on oxygen uptake by "resting cells" of bacteria. J. Bact. 67:4.

Hungate, R. E., D. W. Fletcher, R. W. Dougherty and B. F. Barrentine. 1955. Microbial activity in the bovine rumen, it's measurement and relation to bloat. Appl. Microbiol. 3:161.

Jacobson, D. R. and I. L. Lindahl. 1955. Studies on biochemical, physical and bacteriological factors involved in feed lot bloat. Md. Agr. Exp. Sta. Misc. Publ. 238.

Lord, T. H. 1959. Determinative Bacteriology Laboratory Manual. (2nd ed.) Burgess Publishing Co., Minneapolis, Minn.

Lowenthal, J. P. and S. Berman. 1959. Ovomucinase activity in clostridia. J. Bact. 77:516.

Van Horn, H. H., Jr. and E. E. Bartley. 1961. Bloat in cattle. I. Effect of bovine saliva and plant mucin on frothing rumen contents in alfalfa bloat. J. Animal Sci. 20:85.

Whitehouse, M. W. and F. Zilliken. 1960. Isolation and determination of neuraminic (sialic) acids. Methods Biochem. Anal. 8:199.

Williams, N. B. and D. O. Powlen. 1959. Human parotid saliva as a sole source of nutrient for microorganisms. Arch. Oral. Biol. 1:48.

TEACHING SELECTION PRINCIPLES WITH HERD RECORDS GENERATED BY AN ELECTRONIC COMPUTER [1]

T. Heidhues and C. R. Henderson

Cornell University, Ithaca, New York

A COURSE in advanced animal breeding at Cornell University is largely centered around the principles of the selection index method and its application in actual breeding plans. Students taking this course have previously had a brief introduction to quantitative genetic principles. Their statistical training is generally limited to an introductory course, but sometimes it is lacking completely. Hence it is usually difficult to bring about a complete understanding of the underlying theory of the selection index method. To enhance the understanding it would be desirable to perform actual selection experiments where the result of a certain breeding program could be observed. However, time and facilities do not permit actual selection experiments with large farm animals.

The obvious alternative would be the requirement of stronger and more advanced statistical training such that the concepts presented in this course could be fully understood and the various possibilities of practical applications could be visualized conceptually. This being frequently incompatible with the schedule of students not specializing in animal breeding an approach was used which facilitates the understanding of possible applications of the selection index method without requiring a thorough statistical background. A selection experiment was conducted first in 1959 and is being repeated in 1960 with simulated dairy herds which were generated by an electronic computer. The technique of using simulated herds was used by McGilliard at Michigan State University and mentioned to one of the authors in 1959.

Selection Goal and Postulated Population

To use this technique successfully two major considerations served as a guide. First, the simulated population had to correspond as closely as possible to situations arising in practical breeding work to demonstrate the difficulties and drawbacks which one is faced with and which in many cases impair the progress expected under idealized situations. Therefore, a specific trait in a distinct population of farm animals was selected. In this case we decided upon milk production in Holstein-Friesian cattle. Milk production was chosen because it plays a dominant role in livestock production. The Holstein-Friesian breed because it is the most widely kept breed in New York State. Environmental conditions such as herd effects and herd-year interactions and the genetic parameters including heritability and repeatability were to agree as closely as possible with New York State conditions. The difficulties presented by unequal amounts of production information on different cows and their relatives in the herd arose naturally as the experiment proceeded. The second consideration was—given the aforementioned conditions—how to keep this population uncomplicated and the herds manageable for the student. Thus the extraneous influence of age on records can be demonstrated with a common calving date for all cows in the herd so that only yearly age factors are required. The temporary environmental herd influences, which in practice manifest themselves as herd-year-season influences, are equally well presented if only one season of calving per year is assumed. Furthermore the selection goal was strictly limited to milk production since this is economically the most important trait under selection in dairy cattle.

Method of Generating a Population

In order to generate a population for the purposes outlined above a mathematical model is defined which is assumed to be representative of the natural population. It contains all factors, fixed or random, which are intended to be considered. The elements of the model must be defined and assumptions, which may be necessary, must be stated.

[1] This paper was presented in the Breeding and Genetics Section of the 52nd Annual National Meeting of the American Society of Animal Production, November, 1960. It is published as an "invitational paper" of the Editorial Board.

The underlying model in our experiment was

$y_{ijklm}=\mu+a_i+gh_j+ph_j+th_{jk}+g_l+p_l+t_{lm}$

where μ=population mean,
a_i=effect of the i^{th} age,
gh_j=genetic effect due to herd j,
ph_j=permanent environmental effect of herd j,
th_{jk}=temporary environmental effect of year k in herd j,
g_l=additive genetic effect of the l^{th} cow,
p_l=permanent environmental effect of the l^{th} cow,
t_{lm}=temporary environmental effect of the m^{th} record of the l^{th} cow,
y_{ijklm}=m^{th} record of the l^{th} cow made in herd j in year k at an age i.

Clearly this is a mixed model. The age effect besides the population mean must certainly be considered as fixed. Elements which are definitely random are additive genetic, permanent and temporary environmental effects as well as the herd-year effect. It is more difficult to decide whether the genetic and permanent environmental herd effects should be regarded as fixed or random. In the present case where the chosen herds shall represent a random sample of all possible herds in New York State it seems justified to consider these as random elements. The following assumptions were made

$E(a_i)=a_i$,

where E denotes average value

$E(gh_j)=E(ph_j)=E(th_{jk})=E(g_l)=E(p_l)=E(t_{lm})=0$,
$E(gh^2_j)=\sigma^2_{gh}$,
$E(ph^2_j)=\sigma^2_{ph}$,
$E(th^2_{jk})=\sigma^2_{th}$,
$E(g^2_l)=\sigma^2_g$,
$E(p^2_l)=\sigma^2_p$,
$E(t^2_{lm})=\sigma^2_t$.

All covariances are assumed to be zero. The random elements of the model are normally and independently distributed.

In the initially generated population the variance of single records was postulated to be

$$\sigma^2_y=\sigma^2_{gh}+\sigma^2_{ph}+\sigma^2_{th}+\sigma^2_g+\sigma^2_p+\sigma^2_t$$

after correction for the fixed elements in the model, namely population mean and age effect. To produce a record or a series of records with this variance, six random normal deviates, which are distributed approximately with zero mean and unit variance, are generated and multiplied by coefficients (λ_1, . . ., λ_6) such that the variance of the generated record equals σ^2_y. Thus a generated mature equivalent record (Z_j) is of the form

$$Z_j=\mu+\lambda_1a_{1j}+\lambda_2a_{2j}+\lambda_3a_{3j}+\lambda_4a_{4j}+\lambda_5a_{5j}+\lambda_6a_{6j}.$$

The a_{ij} ($1\leqslant i\leqslant 6$, $1\leqslant j\leqslant n$, where n= population size) are random normal deviates with mean 0 and variance 1. The λ_i, $1\leqslant i\leqslant 6$, are known constants which are determined from the knowledge about the population they are intended to represent.

According to an analysis of New York data the variance of total milk records is approximately 6,350,000 lbs.[2] and can roughly be partitioned as given in table 1.

TABLE 1. COMPOSITION OF THE UNDERLYING POPULATION VARIANCE

Source of variation	Percent total	σ^2	σ
		lb.[2]	lb.
Records x 10^{-2}	100	635.00	25.20
Between herds	40	254.00	15.94
Genetic herd differences	6	38.10	6.17
Permanent herd environment	22	140.00	11.83
Herd-year interaction	12	76.20	8.73
Within herds	60	381.00	19.52
Additive genetic values	15	95.25	9.76
Permanent effects on production other than additive genetic values	12	76.20	8.73
Temporary effects on single records	33	209.55	14.48

The coefficients needed to generate a mature equivalent record of variance σ^2_y according to the model defined previously are:

λ_1= 6.17
λ_2=11.83
λ_3= 8.73
λ_4= 9.76
λ_5= 8.73
λ_6=14.48

because:

$$E(z^2_j)=\lambda^2_1E(a^2_{1j})+\lambda^2_2E(a^2_{2j})+\lambda^2_3E(a^2_{3j})+\lambda^2_4E(a^2_{4j})+\lambda^2_5E(a^2_{5j})+\lambda^2_6E(a^2_{6j}).$$

Since the a_{ij} are NID (O, 1) this reduces to

$$E(z^2_j)=\lambda^2_1+\lambda^2_2+\lambda^2_3+\lambda^2_4+\lambda^2_5+\lambda^2_6=\sigma^2_{gh}+\sigma^2_{ph}+\sigma^2_{th}+\sigma^2_g+\sigma^2_p+\sigma^2_t=\sigma^2_y$$

which is the desired result.

In order to continue the experiment it is necessary to retain the true breeding value or additive genetic value of the individual. This is composed of the genetic herd effect and the additive genetic effect in the model. The true breeding value of the i^{th} animal shall be denoted as:

$v_j=\lambda_1a_{1j}+\lambda_4a_{4j}$.

It is normally distributed with variance:

$\sigma^2_v = \sigma^2_{gh} + \sigma^2_g$ and mean zero.

The permanent environment of each individual enters into each record and hence must also be kept. It is composed of permanent herd environment and a contribution of each individual. We denote it as:

$w_j = \lambda_2 a_{2j} + \lambda_5 a_{5j}$.

It also follows the normal distribution with mean zero and variance:

$\sigma^2_w = \sigma^2_{ph} + \sigma^2_p$.

Genetic theory tells us that progeny which results from a specific mating obtains a sample half of the genes of sire and dam each. There is no possibility to predict which genes these will be, since they are a random sample. Therefore the breeding value of a progeny is determined as:

$$v_{pj} = \frac{1}{2} v_{sj} + \frac{1}{2} v_{dj} + \sqrt{\frac{1}{2}} \lambda_4 a_j$$

where: v_{pj}=breeding value of the progeny resulting from the j^{th} mating,

v_{sj}=breeding value of sire used in the j^{th} mating,

v_{dj}=breeding value of the dam used in the j^{th} mating,

a_j=random normal deviate (0, 1).

Then we have:

$$E(v^2_{pj}) = \frac{1}{4} E(v^2_{sj}) + \frac{1}{4} E(v^2_{dj}) + \frac{1}{2} \lambda^2_4 E(a^2_j)$$

$$= \frac{1}{4}\sigma^2_v + \frac{1}{4}\sigma^2_v + \frac{1}{2}\sigma^2_g$$

$$\sim \sigma^2_v$$

It will be noticed that the variance of the breeding value of progeny resulting from matings of cows and bulls of the original population does not equal σ^2_v. This is caused by the fact that genetic differences between the initial herds exist. However, the rules of the game state that a common bull stud is to be used by all herds. This will tend to eliminate the genetic herd differences gradually. After a certain number of generations the variance of the breeding values will approach σ^2_g.

The rate of decrease in σ^2_{gh}, that is the variance due to genetic herd differences, proceeds geometrically.

$$E_1(v^2_{pj}) = \frac{1}{2}\sigma^2_v + \frac{1}{2}\sigma^2_g$$

$$= \frac{1}{2}\sigma^2_g + \frac{1}{2}\sigma^2_{gh} + \frac{1}{2}\sigma^2_g$$

$$= \sigma^2_g + \frac{1}{2}\sigma^2_{gh}$$

$$E_2(v^2_{pj'}) = \frac{1}{2}\left[\sigma^2_g + \frac{1}{2}\sigma^2_{gh}\right] + \frac{1}{2}\sigma^2_g$$

$$= \sigma^2_g + \frac{1}{4}\sigma^2_{gh}$$

$$\vdots$$

$$E_n(v^2_{pj''}) = \frac{1}{2}\left[\sigma^2_g + \frac{1}{2^{n-1}}\sigma^2_{gh}\right] + \frac{1}{2}\sigma^2_g$$

$$= \sigma^2_g + \frac{1}{2^n}\sigma^2_{gh}$$

As n approaches infinity this expression approaches σ^2_g.

$E_1(v^2_{pj})$=expected value of the squared breeding value of the j^{th} mating in generation 1,

$E_2(v^2_{pj'})$=expected value of the squared breeding value of the j'^{th} mating in generation 2,

$E_n(v^2_{pj''})$=expected value of the squared breeding value of the j''^{th} mating in generation n.

Hence the disappearance of existing genetic herd differences in artificially breeding herds proceeds rapidly. But a few generations are necessary to have genetic herd differences vanished.

Since this is a course in selection and improvement in the true breeding value is the breeding goal, improvements or changes in herd management are not permitted. Therefore, the permanent environmental herd differences remain constant throughout the experiment. Thus the permanent environmental effect affecting an individual through its entire lifetime is composed of the elements ph_j and p_l in the original model. For each calf born it is generated as:

$w_j = ph_j + p_l$

The ph_j are generated at the beginning of the experiment as $\lambda_2 a_{2j}$ and remain constant. The p_l are generated for each new individual as $\lambda_5 a_{5j}$.

Finally, if a cow makes a record during the course of the experiment this record is composed of contributions from the breeding value (v_l), the permanent environment (w_l) and two effects which are peculiar to just one record of a cow and which are not repeated. These are the herd-year effect or temporary herd environment and a temporary environmental effect peculiar to each record within a herd. Consequently a mature equivalent record is generated as:

$Z_l = \mu + v_l + w_l + \lambda_3 a_{3l} + \lambda_6 a_{6l}$

v_l and w_l are the same as defined previously,

λ_3 and λ_6 are known coefficients and a_{31} and a_{61} are random normal deviates with mean zero and variance one. The population mean μ is added to each record. The mature equivalent record thus generated can be converted to an actual record at any age by multiplying this record by the inverse of age correction factors which are commonly used in practice. In this experiment the New York factors were used.

The variance of a mature equivalent record (Z_1) is:

$$\sigma^2_z = \sigma^2_v + \sigma^2_w + \sigma^2_{th} + \sigma^2_t$$

In the originally generated population the variance of mature equivalent records was:

$$\sigma^2_z = \sigma^2_{gh} + \sigma^2_{ph} + \sigma^2_{th} + \sigma^2_g + \sigma^2_p + \sigma^2_t$$

After a certain number of generations the variance of generated records will be:

$$\sigma^2_z = \sigma^2_{ph} + \sigma^2_{th} + \sigma^2_g + \sigma^2_p + \sigma^2_t,$$

that is the component σ^2_{gh} vanishes for reasons explained previously.

Corresponding to the situation prevailing in the population one is attempting to imitate, one has to decide upon a certain fraction of the herd leaving each year for reasons not connected with production. We shall call this a fraction leaving because of "random mortality". This random mortality in a dairy herd corresponds to disposals caused by infertility, injuries, diseases or other losses caused by extraneous circumstances and not based on production. For that matter deliberate culling on the basis of type will fall into this category. The random mortality in our experiment is 0.18. It was higher initially (0.22), but this was reduced to give more latitude for deliberate culling on the basis of production information.

In the bull stud a random mortality fraction of 0.25 was assumed in 1959. However, this proved to be rather high and was reduced to 0.18 in the second year of the experiment.

Procedures Followed During the Course of the Experiment

In the following a brief sketch is given concerning the procedures used at Cornell. We do not claim that these are the best possible ways of conducting such an experiment, but present them as an example of how it can be organized. A week in the experiment represents a year in practice. The essential steps are:

Initial Herds

The initial herds are distributed at the beginning of the course. If we start in year 1 and 2 (hypothetically, of course) with an unknown group of herds with unknown cows, these cows have progeny in year 3 and 4 out of unknown sires. Out of the progeny of year 3 a total of 15 sires is randomly selected subject to the restriction that not more than one bull per herd can be selected. These bulls are randomly mated in year 4 with cows of years 1, 2, and 3. The first production records are generated for year 4. The herds are first distributed to students at the start of year 5. At this time they are composed of:

(a) cows born in year 1 with a record completed in year 4,
(b) cows born in year 2 with a record completed in year 4,
(c) heifers born in year 3 out of cows of group (a) above,
(d) heifers born in year 4 out of cows of groups (a) and (b),
(e) male and female calves born in year 5 out of cows of groups (a), (b) and (c) above, and from bulls of group (f),
(f) 15 bulls in the bull stud out of cows of group (a) above.

The sires of all animals except those under (e) are unknown, the dams of groups (a) and (b) are also unknown.

Identification

A seven digit code is used to identify each animal. This code is:

shhyyww

where: s represents sex (2 = male, 1 = female),
hh represents herd number,
yy represents year of birth, and
ww represents individual number within a herd.

If parents of an individual are unknown they are given the number 000000. A year is defined as beginning with freshening and carries through the completion of the lactation initiated by these freshenings. It is assumed that all cows freshen within a short period of time and at the same time each year, that is, near the cow's birthday. Thus one needs not be concerned about seasonal differences and about age adjustments which are more detailed than factors for 24, 36, 48 etc. months of age at freshening.

Herd Composition and Mortality Rates

Each herd is required to start a year with exactly 30 fresh cows, at most 12 yearling heifers and at most 12 heifer calves. The 30

cows are selected from the survivors of the previous year's milking herd and from the survivors of the heifers that were bred during the past year as yearlings.

If a calf was born at the start of the current year to one of the above animals, the latter is regarded as a survivor. The probability that a calf is born is 0.82. The probability that a calf born is a female is 0.49. Twin births are not permitted.

The maximum of 12 heifer calves permitted to start a year are selected from females born to the first 30 cows described previously. All of the 12 calves selected will live to one year of age. Thus the 12 yearling heifers to start a year will be the ones that were selected as calves one year earlier.

Decisions To Be Made Each Year

To maintain the herd composition just described the following decisions must be made at the start of each year,

(a) which 30 cows and heifers of those just freshened will be kept in the milking herd,
(b) which 12 heifer calves of the crop just born will be selected for possible replacements two years hence, and
(c) which bull will be mated to each of the 30 cows and 12 yearling heifers.

Bull Stud

All herds use bulls from a common stud, the bulls for which will be selected from the herds by a rotating sire selection committee.

At the beginning of each year the stud should number 20 bulls of all ages. The probability of any bull becoming infertile or leaving the stud for reasons other than production is 0.18. The sire selection committee may cull any bull at the beginning of a year and should then add sufficient bull calves to restore the number to 25.

Information for Each Herd

At the beginning of each year the following types of information are furnished to each student,

(a) lactation record for each cow in the herd containing
  (i) individual number
  (ii) sire number
  (iii) dam number
  (iv) year in which the record was made
  (v) actual record
  (vi) mature equivalent deviation from herd average
  (vii) number of records
  (viii) average mature equivalent deviation from herd average,
(b) progeny records
  (i) calf number
  (ii) sire number
  (iii) dam number
(c) mortality
  (i) individual number
  (ii) sire number
  (iii) dam number.

Results of the First Year

The procedure outlined in this paper was generally well accepted by the students participating in the experiment. In our judgment it was successful as an aid to a better understanding of selection principles and the selection index procedure.

Immediately after starting the experiment the student must decide on some sort of a record keeping system in order not to lose sight of individuals and their relatives. The next problem is to find a method of ranking the animals, that is, to estimate their breeding value. This is treated concurrently in class. At the beginning only one record on each cow or her dam is available. Hence the problem of ranking these is simple. But soon more information becomes available and the question arises how to utilize this additional information. Thus the topics covered in class are not hypothetical cases far from practical significance, but they give the solution to problems and answers to questions which arise naturally in pursuing the goal of making maximum genetic progress in a specific herd. The question of the relative importance and the proper weights to be given to the individual's records, its pedigree information and its progeny performance come up before they are discussed in class.

Another important problem is the employment of certain shortcut-methods in indexing the herd. There was sufficient room for culling some of the cows each year, the replacements had to be selected, proper matings were to be made, in short the necessity of ranking the cows of the herd at least approximately arose each week. After a certain time it was too laborious to use the exact selection index method taking into account all information on all relatives. Hence compromises between

accuracy of estimation and feasibility of computations were to be decided upon.

The experiment permitted measurement of genetic progress in a relatively simple way. Since all true breeding values were retained, genetic progress could be measured by the average breeding value of all incoming heifers each year. Figure 1 presents the average breeding values of all incoming heifers in the population.

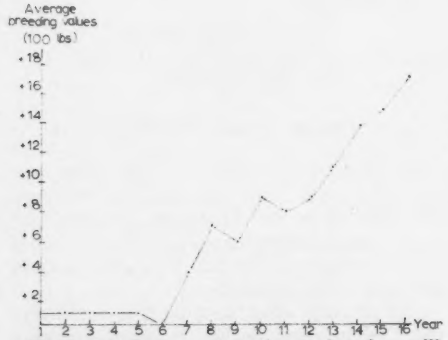


Figure 1. Average breeding value for milk yield (deviation from population average) of all heifers entering the herds.

It will be observed that the average breeding value follows closely the population average—it should be remembered that the breeding values are postulated to be distributed with mean zero—up to and including year 6. During these years the herds consisted mainly of animals which belonged to the original, randomly generated population or were the result of matings with randomly selected sires. A sharp increase occurs immediately after the first sire selection during the years 7 and 8. Then a period of relatively slow or no progress follows throughout years 9 to 12. This is the time where the best ones of the initially randomly selected sires were used along with young bulls chosen on a pedigree basis. A further push forward occurs beginning with year 13 and continuing towards the end of the experiment. This is the time where only sires resulting from a progeny sampling program were used along with a few young bulls selected for sampling purposes.

For individual herds the trend in the genetic herd means was different for three different groups. The first group consisted of herds which were, on an average, genetically inferior at the beginning of the experiment. Even average bulls could do some good in these herds and, therefore, they indicated a steady increase in their mean from the start to the end. The second group comprised a group of herds whose genetic average was close to the population average. These herds maintained their level through the first six years and began to increase their mean beginning with year 7 as better bulls became available or more information on the former ones became available. The final group included those herds which were above average at the beginning. Since the bulls which were available in the first stage were only breed average these herds lost necessarily with respect to their average genetic merit. Afterwards with progeny tested bulls available they picked up again. However, they were not able to regain their former margin of superiority.

In our opinion the results indicated strikingly the points which need to be emphasized in a dairy cattle breeding program, namely to try to estimate the breeding value within herds as accurately as possible and to employ great care in selecting and proving enough young bulls. It might be mentioned that one of the major points is to illustrate that an absolute production record in the presence of permanent and temporary environmental herd differences is not a good basis to estimate an animal's breeding value, and that in such a case the deviation from stablemate average is much more valuable.

This technique is, of course, applicable in many situations. One can well imagine that if the majority of students is more interested in other species of livestock, one chooses a trait in this species. There is also the possibility of expanding such an experiment to select for two or more traits at a time which may or may not be correlated. However, it seems to us that this is not feasible in a one-semester course. The application would run too far ahead of the theory. In a two-semester course such a scheme might be used for the second term.

ABSTRACTS OF PAPERS PRESENTED AT THE MEETING OF THE WESTERN SECTION, A.S.A.P., JULY 16, 17, 18, 1961 MOSCOW, IDAHO

1. NOCTURNAL BEHAVIOR OF BEEF CATTLE IN THE FEEDLOT DURING THE SUMMER. C. B. Roubicek and Farris Hubbert, Jr., *University of Arizona, Tucson.*

The study was conducted to learn the normal nocturnal behavior of beef cattle in the feedlot to determine if a management procedure could be introduced to increase feed consumption. Forty-eight yearling steers were used in the study at the Arizona Agricultural Experiment Station, Yuma, Arizona. Rations consisted of barley, alfalfa, and cottonseed meal with concentrate levels of 33, 55, and 80%. Observations of animal location and activity were made at 20-minute intervals from 8:00 p.m. until 6:00 a.m. twice weekly from July 5 to August 24, 1960. It was found that approximately 90% of the animals were lying down during the hours of darkness. Less than 10% of the steers were eating at any time during the night. Approximately 20% of the animals were under the aluminum shade during the hours of darkness. Brief storm periods provided an exception to the normal behavior pattern. The animals exhibited considerable activity during the squall but quickly resumed the normal pattern after the storm passed. The exceptional behavior pattern found indicates that it may be possible to introduce nocturnal management procedures that will increase feed consumption of beef cattle during the summer months in the Southwest.

2. EFFECT OF TIME OF WEANING ON WINTER PERFORMANCE OF HEREFORD CALVES. Joe D. Wallace and R. J. Raleigh, *Squaw Butte Experiment Station, Burns, Oregon.*

The effect of time of weaning on winter performance of range calves was studied over a two-year period. In 1959, calves weaned on September 9 gained at a significantly higher rate over a 70-day period than similar calves weaned on October 7. In 1960, 54 uniform Hereford calves were stratified by weight and randomly allotted to two experimental treatments on September 15. One group was weaned and placed on a wintering ration consisting of meadow hay *(ad libitum)*, 2 lb. barley, and 1 lb. of cottonseed meal per head daily. The other group was left on sagebrush-bunchgrass range with their dams until October 18, 1960, at which time they were weaned and placed in the same lots and on the same feed as the early-weaned calves. The calves weaned in September were 177 days of age at weaning, while those weaned in October were 214 days of age. Weight gains of unweaned calves during late September and early October were 0.41 lb. per day as compared to 0.84 for the weaned calves during the same period. Over a 208-day wintering period, extending from September 15, 1960 to April 12, 1961, early weaned calves gained at a significantly higher rate than calves weaned at the later date.

3. RESTRAINT OF CATTLE FOR INDIVIDUAL FEEDING. C. C. O'Mary and Douglas D. Bennett, *Washington State University, Pullman.*

Four years' data has been obtained on restraining of purebred cattle for individual feeding. The objective was to determine the time necessary to train animals to go to their respective feeders and become sufficiently gentle to achieve minimum tying time. Data on a total of 110 Angus, Herefords and Shorthorn bulls and heifers was obtained. The same facilities were used each year, but the number of animals per pen, the pre-test period, and personnel were different each year. A four-year average of the data was taken to give a more accurate picture of what could be expected in practice. The first time the animals were chained required an average of 9.1 man minutes per animal. The second tying required an average of 4.2 man minutes. By the end of the first week, the average time required to tie an animal was reduced to an average of 1.3 minutes, and at the end of the second week, 0.58 minutes. Size of pen, number of animals per pen, length of pre-test period, and personnel are factors that seem to affect tying time.

4. MOUNTAIN MEADOW FORAGE AND BEEF PRODUCTION AS AFFECTED BY COMMERCIAL NITROGEN. Forrest M. Willhite, *Colorado State University and U. S. Department of Agriculture, Grand Junction.*

Mountain meadow forages, which over a 7-year period produced a pasture and hay ration consisting of 36% clovers, 24% orchard and 40% other grasses from no nitrogen fertilization, as compared with a ration containing 9% clover, 53% orchard and 38% other grasses produced from annual application of 180 lb. of nitrogen fertilizer per acre, were fed ad libitum to the following classes of livestock: (1) purebred replacement yearling heifers to drop of first calf at 3 years old; (2) 3 calf crops from (1); and (3) grade replacement heifers from weaners to long yearlings. Hay production from grass-legumes was 2.7 tons, as compared with 4.3 tons per acre from nitrogen fertilization. Average daily gain of all replacement heifers was 1.35 lb. on grass-legume ration, compared with 1.17 lb. on grass produced with nitrogen fertilization. Feed intake was 16.5 and 15.5 lb. per day, or 2.266 and 2.223 lb. per 100 lb. of live weight. Feed efficiencies were 13.05 and 13.40 lb., respectively. There was no difference between the two rations as measured by the weights of 3 sets of weaner calves. These average data indicate that 1 acre of grass-legume would carry a yearling heifer 327 days and produce 490 lb. beef per acre, as compared with nitrogen fertilized grass of 555 days, and 638 lb. beef per acre. This integration of growth rate, feed intake and feed efficiency of livestock and the yield of hay would indicate that it is more profitable to utilize commercial nitrogen as a source of nitrogen

for mountain meadow forage production, both hay and pasture, than to depend on the nitrogen produced from the grass-legume association.

5. APPARENT DIGESTIBILITY AND VOLATILE FATTY ACID STUDIES WITH ALL-BARLEY FATTENING RATIONS FOR BEEF CATTLE. W. T. Hayer, III, R. E. Taylor, and Farris Hubbert, Jr., *University of Arizona, Tucson.*

Nine Hereford yearling steers were individually fed either steam-rolled or dry-rolled barley in an "all-barley" fattening ration for 111 days. The barley was fed *ad libitum* plus 1 lb. of supplement per day. The supplement consisted of cottonseed meal 84%, molasses 10%, dicalcium phosphate 5%, salt w/trace minerals 1%, and 10,000 I.U. vitamin A per lb. supplement. Five steers were fed steam-rolled barley and 4 dry-rolled barley for the first 53 days of the trial. The barley preparations were then switched for the 2 groups of steers for the remaining 58 days. No consistent difference in rate of gain or feed conversion was found due to barley preparation. The 9 steers gained 2.0 lb. per day and required 869 lb. feed per 100 lb. gain. Five-day total fecal collection digestion trials were conducted with all steers during each phase of the study. No difference in digestibility of gross energy, crude protein or starch was found due to barley preparation. The digestion coefficients for gross energy, crude protein, and starch were 79.7%, 74.6%, and 95.2%, respectively. Rumen fluid samples were obtained for volatile fatty acid (VFA) analysis 70 and 110 days after initiating the study. No significant difference in total concentration or molar percent of VFA was found between barley treatments at 70 days. However, at 110 days rumen fluid from steers fed dry-rolled barley contained 1229.8 mg. VFA per 100 ml. as compared to 810.7 for those fed steam-rolled barley. Molar percent of acetic, propionic, butyric, and higher fatty acids were 23.9, 59.5, 8.7, and 7.8, respectively, for dry-rolled and 32.6, 49.1, 10.1, and 8.2 for steam-rolled barley fed steers. The high propionate production can provide at least part of the explanation for the efficient conversion of feed to gain with the "all-barley" ration. No vitamin A storage was found in any of the livers at the end of the study which suggests that 10,000 I.U. of vitamin A per day is not adequate for beef steers fed a high concentrate ration.

6. FATTENING CATTLE ON HIGH CONCENTRATE RATIONS. O. O. Thomas, Gary Wilcock, Gary Cowman, and L. G. Young, *Montana Agricultural Experiment Station, Bozeman.*

A high-barley ration was used in two cattle fattening trials. In trial 1, 16 yearling Hereford heifers averaging 560 lb. were divided into two groups. They were hand-fed steam-rolled barley, 2 lb. of a 20% protein supplement and grass hay; the supplement for lot 2 heifers contained 1 gm. of Dynafac per lb. The hay was gradually removed and discontinued after the 28th day. At this time, the heifers were fed steam-rolled barley in a self-feeder and the supplement was fed daily. The trial lasted from June 21 to October 25, 1960—a period of 126 days. The average daily consumption of barley was about 17 lb. The control heifers gained 2.98 lb. per head per day and required 643 lb. of feed per hundred lb. gain. Lot 2 heifers fed 2 gm. of Dynafac per day gained 3.04 lb. per head per day with 631 lb. of feed per hundred lb. gain. In trial 2, 32 yearling Hereford steers averaging 640 lb. were divided into four lots. They were weighed on experiment on June 9, 1960 and weighed off the trial on December 5, 1960. They were hand-fed throughout the trial. They were given steam-rolled barley and 2 lb. of a 20% protein supplement. Lot 1 steers served as the controls, Lot 2 steers received 2 gm. of Dynafac in their supplement, Lot 3 steers received .00375 lb. Agrozyme in the supplement; and Lot 4 steers received both Dynafac and Agrozyme in the supplement. Lot number, average daily gain, and feed required per hundred pounds gain are as follows: Lot 1, control, 2.75 lb., 735 lb.; Lot 2, Dynafac, 2.79 lb., 725 lb.; Lot 3, Agrozyme, 2.75 lb., 714 lb.; Lot 4, Dynafac plus Agrozyme, 2.77 lb., 716 lb. The addition of Dynafac increased gains slightly in both trials and also decreased slightly the feed required per hundred lb. gain.

7. LYSINE AND STILBESTROL IN SORGHUM RATIONS FOR FATTENING STEERS. P. T. Marion and J. H. Jones, *Texas Agricultural Experiment Station, Spur.*

Sorghum grain and cottonseed meal are deficient in the amino acid lysine. These feeds are two of the most important components of rations used in fattening beef cattle in the Southwest. Forty steer calves averaging 507 lb. were divided into four lots of 10 head to determine the value of adding lysine, stilbestrol, and a combination of lysine plus stilbestrol to a ration consisting of 7.8 lb. sorghum grain, 1.0 lb. cottonseed meal, 2.0 lb. whole cottonseed and 25.0 lb. sweet sorghum silage (25% dry matter). The four lots of steers were fed the following amounts of these two additives per head daily: none, 10 gm. lysine hydrochloride, 10 mg. stilbestrol, and 10 gm. lysine plus 10 mg. stilbestrol. Daily gains for the 154-day feeding period were: 1.93 lb., 1.91 lb., 2.09 lb., and 2.26 lb., respectively. Feed required per 100 lb. of gain amounted to 884 lb., 891 lb., 816 lb., and 755 lb. with silage containing 25% dry matter. Lysine alone did not increase gains nor improve feed efficiency. The steers fed lysine plus stilbestrol required 14.6% less feed per cwt. gain than those in the control group and 6.9% less than those fed a higher concentrate ration containing 12.1 lb. grain stilbestrol alone. Another group of 9 steers was fed and 17.8 lb. silage with lysine plus stilbestrol. Their average daily gain was 2.41 lb. and 811 lb. of feed were required per 100 lb. gain.

8. A CONSTANT-INGREDIENT RATION VS. VARIABLE-INGREDIENT RATIONS FOR FATTENING YEARLING STEERS. Conrad J. Kercher and Wilson P. Miskimins, *University of Wyoming, Laramie.*

Sixty-eight yearling steers (684 lb.) were assigned at random to eight groups (8 or 9 per group). Two groups of steers were fed each the following rations: constant-ingredient (controls), variable corn silage, variable grain, and a beet pulp pellet ration. The proportion of feeds in the constant-ingredient ration was not changed during the feeding period. The steers fed the variable silage ration received decreasing proportions of silage during the feeding period. The steers fed the variable grain ration were started on dried beet pulp. Barley replaced the pulp, and, after 84 days, the steers were switched to shelled

corn. The rations were isonitrogenous. The 170-day daily gains and the feed required per 100 lb. of gain were as follows: 2.61, 908; 2.47, 878; 2.39, 972; and 2.17, 897 for the above groups respectively. The beet pulp pellet-fed steers gained significantly slower than the steers fed the other rations. The differences in gain among the other groups were not significant. The pulp pellet-fed steers lost significantly more weight from the end of the feeding period until slaughter than did the control steers. There were no significant differences in the shrink of the other steers. The feeding regimes did not significantly influence the live selling price; live grade; intransit shrink to the packinghouse; carcass grades; cooler shrink; carcass yield; length of body; length of loin; depth of round; or depth of body. The return over feed costs was $15.88, $13.78, $10.34, and $9.01, for the four groups respectively.

9. THE EFFECT OF SUPPLEMENTAL HAY ON GAIN AND FEED CONSUMPTION OF BEEF CALVES FED AN ALL PELLETED RATION. C. C. O'Mary, Gary Smith and M. E. Ensminger, *Washington State University, Pullman.*

The effect of supplemental grass hay fed with an all pelleted ration was studied to determine its effect on average daily gain and feed consumption of calves. Nineteen animals were allowed free access to hay in addition to their twice daily feedings of a pelleted mix containing 50% alfalfa hay. Nineteen animals received pellets only. The average daily gain for animals on pellets alone was 1.67 lb. and for those on pellets plus hay was 1.77 lb. Analysis of variance indicated no significant differences between rations, but there was a highly significant sex difference with bulls gaining 2.12 lb. per day and heifers gaining 1.63 lb. daily. The feed consumption of calves on pellets alone was 12.99 lb. per head daily and for the other group was 11.93 lb. of pellets and 5.44 lb. of hay. The feed efficiency for calves on pellets alone was 755.5 lb. of feed per cwt gain. For calves with access to hay, the feed efficiency per cwt. gain was 698.4 lb. of pellets plus 323.9 lb. of hay.

10. THE NET ENERGY OF BARLEY STRAW FOR FATTENING CATTLE. G. P. Lofgreen and Allen C. Christensen, *University of California, Davis.*

Because of the relatively good results often reported from feeding barley straw in fattening rations it was deemed desirable to reinvestigate the value of this roughage as a source of net energy (NE). Forty-eight Hereford steers were used in a $2 \times 2 \times 2$ factorial design with three replications. The factors studied were roughage source, roughage level and method of feeding. Body composition of representative animals initially and all animals finally was determined from specific gravity measurements on the dressed carcasses. The empty body weight and reticulo-rumen fill were determined at slaughter and liveweight gains corrected for fill. The combined data showed that all rations containing straw produced apparent liveweight gains amounting to 95% of that of alfalfa rations. When corrected for fill the figure was 88% and when energy gain per 100 lb. of feed was measured the straw rations produced only 82% as much as those containing alfalfa. Straw fed animals had 53 lb. of fill while consuming 16.3 lb. of feed per day while animals fed alfalfa had only 28 lb. of fill while eating 17.2 lb. of feed. The dressing percent for the two lots was 59.7 and 61.9, respectively. The concentrate portion of the ration had a NE content of approximately 56 mcal. per 100 lb. Alfalfa and straw had NE values of 44.4 and 23.0 mcal. per 100 lb., respectively.

11. AN APPARATUS FOR COLLECTING EXCRETA FROM GRAZING CATTLE. A. L. Lesperance and V. R. Bohman, *University of Nevada, Reno.*

A portable apparatus is described that quantitatively collects feces and urine from cows and heifers without contamination. This equipment employs an inflatable urethral catheter that is connected to a collecting container that is carried on the back of the animal. A vinyl-coated fecal collecting bag is also used. This equipment is simple, relatively inexpensive and has been successfully tested under a wide variety of conditions.

12. ESTIMATIONS OF FEED INTAKE AND DIGESTIBILITY BY 4, 6 AND 24-HOUR FECAL COLLECTIONS USING LIGNIN AS THE INDICATOR WITH HEIFERS. Kenneth R. Hill, W. W. Repp, W. E. Watkins and J. H. Knox, *New Mexico State University, University Park.*

In the first part of the trial two 2-year-old heifers were fitted with feces bags designed for separate collection of feces. Twenty-four hour feces collections were made three times for each heifer during a 7-day period during which 16 lb. of a pellet containing 70% ground alfalfa, 25% ground milo and 5% molasses was fed daily. Feces bags were emptied at 8-hour intervals during the 24-hour period. Percent lignin recovery in the feces for the six collections was 123.58, 134.32, 114.69, 119.73, 88.87 and 119.36 indicating considerable overstimulation in fecal output. This overstimulation was reflected in lowered feed digestibility especially in the crude fiber fraction. In the second part of the trial comparisons were made of 4 and 6-hour fecal output of single heifers fitted with feces bags as compared with amount of feces voided by seven heifers without bags confined for like periods on a 10′ x 20′ concrete platform. Percent lignin recovery in the feces of the two heifers with feces bags was for the four 4-hour collection trials 93.72, 117.28, 124.62 and 79.29 as compared with 87.73, 59.96, 63.80 and 102.34 for the seven heifers on the platform. Percent lignin recovery for the four 6-hour collection trials was 40.95, 104.30, 117.22 and 107.19 for the two heifers with feces bags and 48.08, 70.20, 71.99 and 77.99 for the seven heifers on the platform. Four-hour and six-hour feces collections were assumed to represent ⅙ and ¼ of the 24-hour feed consumption respectively for purposes of calculation.

13. THE ESTIMATION OF RETICULO-RUMEN FILL OF BEEF CATTLE. G. P. Lofgreen and J. L. Hull, *University of California, Davis* and K. K. Otagaki, *University of Hawaii, Honolulu.*

One hundred and four Hereford steers were used in a study to determine the amount of fill remaining in the combined reticulum and rumen after a 24-hour shrink without feed and 12 hours without water. Liveweight measurements were taken immediately prior to slaughter and the reticulo-rumen contents and warm carcasses were weighed at the packing plant. The "empty body weight" was de-

termined by deducting the reticulo-rumen fill from the shrunk liveweight. The regression of the empty body weight on warm carcass weight is described by the linear equation, $Y = 70 + 1.45\ X$ where Y is the empty body weight in pounds and X is the warm carcass weight in pounds. The standard error of the regression is 0.01 and the correlation coefficient is 0.97. The coefficient of determination of 0.94 indicates that only 6% of the variation in empty body weight remains unaccounted for when it is estimated from the above equation from warm carcass weight. A multiple regression analysis indicates that fill exerts twice as much influence upon dressing percent as does carcass fat percentage and that shrunk body weight independent of the other two factors has no influence. The reticulo-rumen fill of beef cattle can be accurately determined by estimating empty body weight from warm carcass weight. The difference between the shrunk liveweight and the empty body weight represents the fill.

14. USE OF A SIMPLIFIED ARTIFICIAL RUMEN TECHNIQUE TO ASSESS THE NUTRITIVE VALUE OF VARIOUS TALL FESCUE SAMPLES. D. M. Bowden and D. C. Church, *Oregon State College, Corvallis.*

Thirty-nine samples of four genotypes of tall fescue *(Festuca arundinacea)* harvested at pasture height over a four-year period were digested *in vitro* and *in vivo*. *In vitro* digestions were carried out in 250 ml. centrifuge bottles with diluted rumen liquor for 48 hours. Digestibilities of dry matter and cellulose were determined. Residue from the centrifuge bottles which would not pass through a sintered glass disc crucible was considered to be indigestible. Samples of an alfalfa hay were included in all trials to give a measure of the variability of the digesting power of the rumen liquor inocula used at different times. Within-trial variation between centrifuge bottles in *in vitro* dry matter digestibility was generally small. Cellulose digestibility showed a slightly higher within-trial variability. Results from 13 trials in which the control alfalfa was included showed a significant difference in the digesting capacity of rumen liquor collected from a steer on different days. The correlation between *in vitro* dry matter digestibility and *in vivo* dry matter digestibility of tall fescue samples was highly significant. Correlations were lower for those samples held in storage for the longest periods. *In vitro* dry matter digestibility as determined in this study is as reliable as *in vitro* cellulose digestibility for estimating *in vivo* digestibility of forage. Oven-dried (50° C.) samples were more satisfactory than fresh-frozen samples for *in vitro* digestion. Volatile fatty acids were produced in amounts and proportions as expected from digestion of forage by rumen microorganisms.

15. THE EFFECT OF FEEDING HIGH LEVELS OF VITAMIN A TO BEEF CATTLE UPON PERFORMANCE AND TISSUE VITAMIN A LEVELS. W. H. Hale, Farris Hubbert, Jr., R. E. Taylor, T. A. Anderson and Bruce Taylor, *The University of Arizona, Tucson.*

Twelve yearling steers averaging 731 lb. were allotted into six treatments based on liver vitamin A values. The steers were individually full-fed a 65% rolled milo: 35% cottonseed hull mixture plus 2 lb. of a cottonseed meal supplement daily. Daily vitamin A intake by treatment was as follows: (1) none, (2) 10,000 I.U., (3) 40,000 I.U., (4) 160,000 I.U., (5) 640,000 and (6) 2,500,000 I.U. The vitamin A was added to the cottonseed meal as gelatin stabilized synthetic vitamin A palmitate. The steers were fed for a 168-day period. Liver biopsies and blood samples were taken at regular intervals throughout the duration of the experiment. No general relationship existed between plasma vitamin A and liver vitamin A values, however, the highest level of A feeding did result in the highest plasma A values. The plasma A concentration of the control steers declined throughout the experiment. With the other treatments, plasma A values remained fairly constant after the second day. Liver A values with the three higher level treatments increased throughout the experiment with a value of 5000 mcg. per gm. noted in the livers of treatment 6 at the termination of the experiment. Treatment 2 failed to maintain initial liver A values, however, treatment 3 did, but no increase occurred over the initial value. With the 7 other tissues studies, only fat showed an increase in vitamn A content and in that case only with treatment 6. The higher levels of A feeding did not appear to produce undesirable effects in the animals. Rate of gain and feed intake was similar for all treatments.

16. THE INFLUENCE OF GRADED LEVELS OF ALFALFA AND ANIMAL FAT ON THE GROWTH AND TISSUE COMPOSITION OF BEEF CALVES. V. R. Bohman, M. A. Wade and C. R. Torrell, *University of Nevada, Reno.*

Seventy-two weanling calves were allotted to the following treatments during a 2-year period in a factorially-designed experiment: two levels of fat, 0 and 0.5 lb. daily, and three levels of pelleted alfalfa, 0, 3 and 6 lb. daily. The basal ration was native grass hay and a mineral mix composed of equal parts of bone meal and salt. These feeds were fed during the winter period. During the summer all cattle ranged together without supplements except the mineral mix. The following results were obtained during the winter period: Daily gain, body measurements and feed consumption increased with each increment of alfalfa. Fat had no effect on these items. Fat and protein influenced the amount of plasma fat, cholesterol, carotene and vitamin A. The highest levels of these blood constituents occurred on the high fat-no alfalfa ration; the high fat-alfalfa supplemented rations were intermediate and the low-fat rations were least. Dietary fat increased the amount of carotene and cholesterol in the liver and the plasma lipid phosphorus. As the amount of alfalfa increased in the ration, the storage of vitamin A in the liver decreased. Alfalfa levels also influenced the hematocrit. Summer values for the blood and liver constituents were not influenced by winter treatments. During the summer, weight changes and body measurements were inversely related to the winter response.

17. THE PERFORMANCE OF WEANER CALVES AS INFLUENCED BY LOW LEVELS OF ALFALFA IN THE WINTERING RATION. R. J. Raleigh and Joe D. Wallace, *Squaw Butte Experiment Station, Burns, Oregon.*

Forty weaner calves were stratified by weight and sex and randomly allotted to four treatments with ten animals per lot. Each lot of calves was randomly

assigned to one of the following treatments: (1) Control group receiving 1 lb. of cottonseed meal per head daily, (2) 0.22 lb. of cottonseed meal and 2.0 lb. of alfalfa meal per head daily, (3) 0.5 lb. of cottonseed and 1.33 lb. of alfalfa meal per head daily, and (4) 0.75 lb. of cottonseed meal and 0.67 lb. of alfalfa meal per head daily. All the steers received native meadow hay free choice and 2 lb. of rolled barley per head daily. The cottonseed and alfalfa meals for each treatment were mixed with the barley and fed daily in feed bunks. The meadow hay was fed daily in hay mangers. The steers were weighed every 2 weeks during the 16-week feeding trial. The average daily gains, daily meadow hay consumption, feed per 100 lb. gain, and feed costs per 100 lb. gain, respectively for each treatment were: (1) 1.38 lb., 10.6 lb., 986 lb., and $13.84; (2) 1.29 lb., 9.8 lb., 1,086 lb., and $15.55; (3) 1.32 lb., 10.0 lb., 1,050 lb., and $15.11; and (4) 1.59 lb., 10.9 lb., 898 lb., and $12.57. The differences in average daily gain were significant with the steers receiving the low level of alfalfa (Treatment 4) gaining significantly more than the other 3 groups. Meadow hay consumption was significantly lower in the two groups of animals receiving the higher level of alfalfa.

18. FACTORS INFLUENCING TALLOW UTILIZATION IN ARIZONA FEEDLOT RATIONS. Farris Hubbert, Jr., Bruce Taylor, E. B. Stanley, W. H. Hale, and John Kuhn, *University of Arizona, Tucson.*

Feedlot studies were conducted with yearly steers during 1960 and 1961 at the Arizona Agricultural Experiment Station, Yuma, Arizona. The 1960 study was conducted as a 2 x 2 x 2 factorial with 112 steers. The factors studied were: protein level (10 vs. 13%), addition of rendering plant tallow (none vs. 4%), and the addition of 0.1% calcium as limestone (no added Ca vs. 0.1% added Ca). The mixed ration consisted of: ground milo and cottonseed meal, 55%; chopped alfalfa hay, 15%; and, cottonseed hulls, 30%. The proportion of milo and cottonseed meal was varied to provide the desired crude protein level. The protein levels studied resulted in a significant difference in average daily gain. The daily gain and feed required per 100 lb. of gain for steers fed 10 and 13% protein levels were: 3.22, 1031 and 3.42, 938, respectively. The addition of 4% tallow resulted in a slight depression in feed intake but had no significant influence on rate of gain. However, the addition of tallow produced more efficient conversion of feed to gain (935 vs. 1034 lb. of feed per 100 lb. of gain). The addition of 0.1% calcium had no significant influence on performance of the steers. The 1961 study was conducted as a 2 x 3 factorial with 96 yearling steers. Forty-eight steers (replication 1) had been fed a growing-fattening ration for 6 months prior to being reallotted to this study. The 48 steers assigned to replication 2 had been fed a small amount of grain during a 3-week preliminary period. The factors studied were: protein level (10 vs. 14%) and the addition of rendering plant tallow (no tallow, plus 4% tallow and plus 4% tallow with 1% dicalcium phosphate). The rations fed to the 12 pens were the same as used during 1960 except that 30% alfalfa and 15% cottonseed hulls were used. Dicalcium phosphate was also added to all rations to maintain a minmum level of 0.3% phosphorous. The replication 2 steers gained significantly more than the "long-fed" steers (3.09 vs. 2.49 lb. per day) and a significant protein level X replication interaction was found. The replication 2 steers gained 3.20 and 2.98 lb. per day on the 14% and 10% protein levels, respectively, while the "long-fed" steers did not respond to the increased protein level. Average daily gains and feed required per 100 lb. of gain for the tallow treatments were: no tallow 2.63, 971; 4% tallow 2.88, 898; 4% tallow and 1% dicalcium phosphate, 2.85, 889.

19. SOME EFFECTS OF HYDROXYZINE ON BEEF CATTLE. John D. Clark, A. T. Ralston and I. A. Dyer, *Washington State University, Pullman.*

Two experiments have been conducted in which hydroxyzine has been fed to beef cattle. In the first experiment, twelve grade Hereford steers weighing 680 lb., were allotted at random into two groups of six each. Group one served as the control and group two received 8.4 mg. of hydroxyzine per head per day. The feeding trial was for 119 days. Average daily gains for the two groups was 2.23 and 2.11 lb. respectively. These differences were not statistically significant. The controls consumed 7.66 lb. of feed per lb. of gain while the treated animals consumed 7.90 lb. In the second experiment, 27 animals were randomly allotted into three groups of nine animals each. Group one served as the control and groups two and three received 2.5 and 50 mg. of hydroxyzine per head per day, respectively. The feeding period was 108 days. Average daily gains were 2.53, 2.65 and 2.61 lb. for the three groups, respectively. Feed consumed per lb. of gain was 8.50, 8.14 and 8.50 lb. while the average number of therms of gross energy ingested per lb. of gain was 15.80, 14.89 and 15.61. Digestibilities of the three rations, determined *in vivo* by the nylon bag technique in a fistulated steer, were 61.9%, 58.2% and 61.6%. Rumen microbial activities were compared for the control and 50 mg. hydroxyzine groups. The treated groups showed the most activity in the Warburg apparatus, releasing 36.43μm of gas per minute compared with 25.86μm per minute for the control.

20. MANGANESE DEFICIENCY AS A POSSIBLE CAUSE OF DEFORMED CALVES. I. A. DYER, *Washington State University, Pullman.*

A congenital malformation of calves is prevalent in the Northwestern United States. This anomaly is typified by either bent fore limbs, bent spine or both. In most cases, the bones essentially are normal in size and gross composition. In order to study this condition, two small adjacent ranches, one with deformed calves and the other without, were selected. Soil classification and analysis, a taxonomical survey and analysis of the plants and also analysis of water was made. Analyses of samples from the two ranches were similar in most respects. The one notable exception was manganese. This element was 17, 33 and 1400% higher in the soil, forage and water from the normal ranch than comparable samples from the ranch on which deformed calves were produced. Furthermore serum samples from normal and deformed calves were analyzed for their alkaline phosphatase contents with the normal calves averaging 28% higher. These data suggest that the deformed calves are a result of a manganese deficiency.

21. EFFECTS OF LEVEL OF SODIUM CHLORIDE CONSUMPTION ON WATER AND MINERAL BALANCE IN BEEF CATTLE. C. J. Elam and L. K. Autry, *Beef Cattle Research Branch, ARS, USDA, Beltsville, Maryland.*

Four Hereford steers were used in a balanced 4 x 4 extra-period Latin-square experiment. Each period included an 18-day preliminary and a 10-day collection period. One, 2, 4, and 8% levels of NaCl were added to a basal ration of grass hay, corn, CSM, and bone meal. Steers were fed the pelleted rations twice a day and water was *ad libitum*. Urine and feces were collected using digestion crates. Pooled aliquot samples of feed, feces, and urine were analyzed for moisture, Ca, P, Mg, Na, K, and Cl. Ca retention increased with each addition of NaCl in the ration up to the 4% level. Fecal excretion of Ca decreased with increasing levels of NaCl. P retention was higher on the 2 and 4% NaCl levels than either 1 or 8%. P excretion in the feces decreased with increasing dietary NaCl but this was offset at the 8% level by an increased urinary excretion of P. Mg. retention was not influenced by treatments. Na retention was greater on the 4 and 8% NaCl treatments than the 1 or 2%. K retention was not influenced significantly by treatments, but tended to decrease with increasing levels of dietary NaCl. Greater urinary excretion of K resulted at the 4 and 8% level of NaCl. Cl retention was higher on the 8% and highest on the 4% NaCl treatment. A significant single period carry-over effect resulted in the Cl data. Water balance (ingested-excreted water) was not affected by treatments. All of the above differences were statistically significant at $P = .05$ or less.

22. APPARENT PATTERNS OF CERTAIN BLOOD ENZYMES IN HEREFORD AND ANGUS CATTLE. W. K. Johnston, Jr., A. F. Anglemier, Ralph Bogart, *Oregon State University, Corvallis.*

Samples of venous (jugular) blood from forty-five calves: twenty-eight Hereford (9 males) and seventeen Angus (6 males). Samplings were made at one-hundred pound intervals covering the period a growth between four-hundred and eight-hundred pounds. Diet was constant and animals were restricted to barn pens throughout the test. Blood serum was analyzed to determine the level of activity of alkaline and acid phosphatase, serum glutamic-oxalacetic and serum glutamic-pyrunic transaminase, amylase, and lipase. Average values for these analyses showed Angus to have 20% higher alkaline phosphatase while acid phosphatase remained essentially the same, when compared to Herefords; the alk/acid phosphatase ratio was 14% higher for Angus as opposed to Hereford; alk/acid phosphatase ratio was higher in female Angus than in male Angus, while just the opposite was the case for Herefords; there was no essential difference between Angus and Hereford males in their alk/acid phosphatase ratios; acid phosphatase demonstrated very little sex or breed differences. Averages show a fairly constant SGO-T/SGP-T ratio of 3 to 1, Angus falling somewhat below this value while Herefords were slightly higher. SGP-T activity was higher in females than in males. Herefords had an average level of amylase activity somewhat higher than Angus, with females just slightly higher than males. Lipase analyses were of no value due to difficulties within analytical methods employed.

23. INFLUENCES OF SEX, SIRE AND ENVIRONMENTAL FACTORS ON PROTEIN FRACTIONS IN THE BLOOD SERUM OF RANGE CALVES. O. F. Pahnish, C. B. Roubicek and Farris Hubbert, Jr., *The University of Arizona, Tucson.*

The relative amounts of albumin and the three globulin fractions (alpha, beta and gamma) in the blood serum of calves weaned at a mean age of 235 days were determined by electrophoretic separation. The 104 calves involved (59 bulls and 45 heifers) were purebred progeny of 5 Hereford sires. The means (in percentages) and standard deviations for albumin and for alpha, beta and gamma globulin, respectively were: 51.3 ± 5.8, 18.2 ± 2.3, 11.7 ± 4.3 and 18.9 ± 4.1. The coefficient of variation for beta globulin was largest and was followed in descending order by those for gamma globulin, alpha globulin and albumin. All fractions were more variable in heifers than in bulls. The influences of sex, age of dam, sire of calf and weaning age on the protein fractions were evaluated statistically by least squares procedures. Albumin percentage decreased with the increase in weaning age by 0.095 per day ($P<.05$), while alpha globulin percentage was not appreciably affected by age. The effects of sex, age of dam and sire on these two fractions were nonsignificant. Beta globulin was influenced significantly by sex and sire only ($P<.05$). Heifer serum contained a higher percentage of beta globulin than did bull serum. Gamma globulin was influenced significantly by sex only ($P<.05$), with the bull serum having the higher percentage of gamma globulin. Although age effects on beta and gamma globulin were statistically nonsignificant, the relative amounts of these fractions increased with weaning age by 0.045 and 0.044 per day, respectively.

24. FACTORS INFLUENCING CALF WEANED WEIGHTS IN A COMMERCIAL ABERDEEN-ANGUS HERD. R. T. Berg, *University of Alberta, Edmonton, Alberta, Canada.*

Four years of weaned weight records involving 665 calves from a large commercial Aberdeen-Angus herd were analysed to compare two methods of appraising preweaning calf performance, to estimate the effects of year, sex of calf, age of calf and age of dam, and to estimate repeatibilty of adjusted preweaning performance. Within year and age of dam correlation coefficients were calculated among weaned age, weaned weight, average daily gain and weight per day of age for each sex separately. A very high positive relationship between average daily gain and weight per day of age ($r=0.98$ for males and 0.97 for females) indicated that both measures should be essentially equal in appraising preweaning gain. However, a higher negative association between weaned age and weight per day ($r=-.40$ and $-.23$) as compared to weaned age and average daily gain ($r=-.22$ and $-.01$) indicated that older calves were placed at a slight disadvantage when weight per day of age was used as the criterion. Least squares estimates using weight per day of age indicated males gained approximately 0.1 lb. per day more than females to weaning. Three-year-old cows had calves about 0.2 lb., 4-year-olds 0.1 lb., and 5-year-olds 0.05 lb. per day below the mature group.

Cows of 6 to 9 years of age produced calves with similar weight per day averages. Repeatibility of adjusted calf weight per day was calculated by intra-class correlation technique yielding an estimate of 31%

25. ELECTROCARDIOGRAMS OF 8 YEAR OLD ANGUS COWS, ONE WITH SEVERE EDEMA. Wm. C. Van Arsdel III and Ralph Bogart, *Oregon Agriculture Experiment Station, Corvallis.*

Phonocardiograms, electrocardiograms and cardiac vector loops in two planes perpendicular to each other are illustrated for two 8-year-old Angus cows. At the time of the electrocardiographic recording one cow, B-65, was presumed to be normal, while the other, B-69, exhibited malaise and severe edema of the brisket area. Cow B-69 was subsequently sacrificed and autopsied. According to the veterinary report, the cow apparently suffered from an acute and severe allergic reaction. The electrocardiogram shows tachycardia with a normal conduction sequence; however, the wave forms are abnormal. The P,QRS and T waves are characterized by their low potential and are difficult to delimit or identify. The first heart sound may be split, but this sound pattern more probably depicts a systolic murmur. Such a murmur is often reported for congestive heart failure in human clinical practice. No similar bovine recording or case history could be found in a literature survey.

26. THE EFFECT OF DIETARY CHANGE ON THE HEART RATE OF BEEF CALVES. Sucheep Retarasarn, Wm. C. Van Arsdel III and Ralph Bogart, *Oregon Agricultural Experiment Station, Corvallis.*

Electrocardiogram (EKG) recordings were obtained from two and six Angus bull calves at 800 lb. body weight using the method described by Van Arsdel, Krueger and Bogart (1959). Records for each calf were obtained before and after removal from the test pens. A pelleted feed (65% alfalfa hay, 35% concentrate) is used in the gain evaluation test for young cattle (500 to 800 lb.) at the Oregon Agricultural Experiment Station. Analysis of the records showed that 800-lb. calves on the test program have a heart rate of approximately 100 beats per minute. Removal from the test environment changed the cardiovascular physiology at least to the extent that the heart rate was more variable and was slowed to a rate of 85 beats per minute. This study substantiates other preliminary observations obtained at this station.

27. SOME URINE UREA-N RELATIONSHIPS IN CATTLE. H. J. Weeth, J. R. Ridley, J. M. Connor and A. L. Lesperance, *University of Nevada, Reno.*

Total urine was collected three times from eight heifers on irrigated, grass pasture and twice from six heifers on the range. Rumen fistulated animals provided samples of the forage. The concentration of blood and urine urea-N was determined. The average percent crude protein in the dry matter of rumen samples from heifers on irrigated pasture was 22.20 compared to 9.75 for heifers on range. The higher protein in pasture forage was associated with a higher blood and urine urea-N concentration and 218% more total urea-N in the urine. The following significant, simple correlations (r) were found: (1) percent crude protein in rumen sample with mg. % urea-N in blood, 0.660; (2) percent crude protein in rumen sample with gm. urine urea-N, 0.662; (3) mg. % blood urea-N with liters of urine per day, 0.507; (4) mg. % blood urea-N with gm. urine urea-N per day, 0.691; (5) liters urine per day with gm. urine urea-N per day, 0.756. It is suggested that these observations are important because Houpt (Am. J. Physiol. 197:115, 1959) has shown that ruminants can use endogenous urea-N in a protein regeneration cycle.

28. INFLUENCE OF ESTROGEN TREATMENT ON OVARIAN ACTIVITY IN POST-PARTUM DAIRY COWS. W. D. Foote and L. Walker, *University of Nevada, Reno.*

Twenty-two Holstein cows were divided at random, within parity (primiparous and pluriparous), into two groups. Each group contained six primiparous and five pluriparous cows. Each cow in one group was given a single intravenous injection of 10 mg. alpha estradiol in corn oil within the range of 9–12 days after calving. The animals of the other group served as untreated controls. Ovarian activity was determined by rectal palpation. All estrogen treated cows come into heat and ovulated the day following treatment except two animals in the treated primiparous group. One of these came into heat and ovulated 3 days after treatment and the other was in estrus the day following treatment but did not ovulate until 35 days after the estrogen injection. The average intervals from calving to first ovulation of all untreated cows was 30.9 days and of all treated cows 14.9 days. The averages and standard deviations, in days, of the intervals from calving to first ovulation for the various subgroups were: untreated primiparous, 39.2 ± 23.5, untreated pluriparous 21.0 ± 6.6, estrogen treated primiparous 17.0 ± 13.3, and treated pluriparous 12.4 ± 0.9. These values for the intervals from the first to the second ovulation for these respective subgroups were 29.0 ± 10.2, 22.4 ± 6.1, 22.3 ± 8.5 and 28.8 ± 10.1.

29. THE PRODUCTION OF BOVINE VIABLE OVA. T. Sugie. M. E. Ensminger, E. H. Rupnow, E. S. E. Hufez, W. L. Hunt and R. E. Mauer. *Washington State University, Pullman.*

Twenty Hereford yearling heifers were used to study the effects of the ovarian conditions prior to treatment in relation to subsequent findings after superovulatory treatment, slaughter, and collection of ova *in vitro*. The heifers were divided into two groups, normal and subnormal, on the basis of estrous and ovulation cyclic behavior. The techniques employed during this investigation involved continual daily rectal palpation and clay model construction of the ovaries. The subnormal group exhibited smaller ovaries after PMS treatment than the normal animals. Forty-two percent of the ova flushed from the subnormal group exhibited cleavage as compared to 54% for the normal group. Eighty-four percent of the normal cows had a follicular response of over 20 follicles, while only 43% of the subnormal cows were in this category. A plausible explanation for the poor fertilization rates associated with bovine superovulation was found in the long interval of ovulation and its concomitant change in hormonal environment. A probable advantage of using animals of normal estrous cycles may be the

presence of ovarian follicles which will respond to PMS.

30. FACTORS AFFECTING CALF WEIGHT GAINS DURING THE SUCKLING PERIOD. Noah England, James S. Brinks, Ralph Bogart, David C. England and R. T. Clark, *Oregon Agricultural Experiment Station, Corvallis, and Agricultural Research Service, U.S.D.A.*

Data collected during 6 years on 214 cows and their calves from four inbred lines were used to study changes in cow weights and calf-weight gains for each of six 28-day periods following parturition. Bulls gained more rapidly than heifers only in the first and fifth periods; the times when conditions encouraged rapid gains for all calves. There were no significant differences between lines in calf gains for the first three periods, but there were line differences in the last three periods. Age of dam affected calf weight gains during the first four periods only. Gains of calves in one line were relatively constant; whereas in the other lines, gains varied by periods. The most important factor affecting changes in cow weight was years, but there was a significant line effect in period six. Age of cow had no effect on her weight change. The significant negative correlations between changes in cow weight and gains in calf weight outside the diagonal, and significant positive correlations on the diagonal indicate that cows gaining in weight in early lactation are poor milkers that may give sufficient milk in early lactation, but have inadequate milk flow later with consequent poor calf gains in the third and fourth periods. The positive correlations of change in cow weight with gains of calves within periods indicates that pasture conditions influence weights of cows and gains of calves similarly within periods.

31. THE RELATIONSHIP BETWEEN SERUM PROTEIN AND GROWTH IN CALVES. Franklin R. Ampy, James S. Brinks, Ralph Bogart and R. T. Clark, *Oregon Agricultural Experiment Station, Corvallis and Agricultural Research Service. U.S.D.A.*

Production traits and blood serum constituents have been studied on 45 calves at 500, 600, 700 and 800 lb. body weight in the 1958 calf crop consisting of three genetically different Hereford lines and one Angus line. Statistical analyses were performed to determine sex and line differences. Data from this study indicated that male calves had higher feed test gains than female calves and required less feed per unit gain. Male calves made more rapid gains than female calves because of greater efficiency of feed utilization rathan than because they consumed more feed. Females ate an average of 0.93 lb./day more feed than males. Daily gains decreased as calves grew from 500 to 800 lb. body weight. Feed required per unit gain increased markedly as calves grew from 500 to 800 lb. body weight. There were no consistent correlations between blood constiuents and production traits, although male calves had higher gamma globulin fractions than female calves when the model holding age as a constant was used. Specific gravity was consistently positively correlated with total serum proteins. Albumin was negatively correlated with the globulin fractions. Alpha globulin was negatively correlated with gamma globulin. The blood constituents and production traits were influenced by age. When age was held constant in the analysis, certain differences that existed when age was allowed to vary disappeared. Conversely in some cases where no differences were noted when age was allowed to vary, there appeared significant differences when age was held constant.

32. THE EFFECT OF VASECTOMY AND VASOLIGATION ON FREE SEMINAL GLUTAMIC ACID IN THE BOVINE. M. L. Hopwood, J. F. Masken and F. X. Gassner, *Colorado State University, Fort Collins.*

Bilateral ligation of the vasa deferentia of two Holstein bulls caused a reduction by 47% in the total free amino acid content of the seminal fluid collected by means of an artificial vagina. Reduction in the seminal glutamic acid was, however, 92%. Bilateral vasectomy in two Holstein bulls caused a loss of 95% of the seminal free amino acids and a complete disappearance of glutamic acid. Sperm were absent from the seminal fluid of the 4 bulls in less than 2 weeks after surgery. Treatment of both vasectomized bulls with testosterone propionate at 100 mg. per day restored the other amino acids (aspartic acid, serine, glycine and alanine) by 32% but only 7% of the original concentration of glutamic acid was restituted. A vasectomized Hereford bull gave a similar but less complete reduction in free amino acids. The presence of a few dead spermatozoa (sperm count reduced 99.4%) in the ejaculate after 7 months and the apparent establishment of a channel for the passage of these cells may account for the different results. These observations offer further evidence that seminal glutamic acid is predominantly a product of the testis and epididymis.

33. THE EFFECT OF EXHAUSTIVE EJACULATION ON QUALITY OF BOVINE SEMEN. M. L. Hopwood, J. F. Masken and F. X. Gassner, *Colorado State University, Fort Collins.*

Repeated collections of semen by use of an artificial vagina (A.V.) from a normal Shorthorn (eight ejaculates) and an infertile Hereford bull (16 ejaculates), were followed by electrical stimulation to produce eight additional samples from each animal. As observed for exhaustive ejaculation in other bulls, the sperm count steadily declined as did the seminal fructose and nitrogen while pH rose. Electroejaculation increased the semen volume in both bulls and the percentage of live spermatozoa in the Hereford. In this bull, continued ejaculation led to a decline in secondary abnormalities and a rise in primaries. The bulls quickly recovered from the procedures and, in addition, the sterile bull showed a definite but fleeting improvement in sperm morphology. An Angus bull behaved uniquely in that 17 A.V. ejaculates were obtained with but a slight decline in sperm numbers and no change in the other semen criteria. This animal delivered 34 billion sperm while total delivery of sperm was 6 and 17 billion for the Shorthorn and Hereford, respectively.

34. CERTAIN WINTER COAT CHARACTERISTICS OF HEREFORD, CHAROLAIS X HEREFORD AND ABERDEEN ANGUS X HEREFORD STEERS. C. M. Williams and W. Noy, *Department of Animal Husbandry, University of Saskatchewan, Saskatoon, Canada.*

A one square inch hair sample was clipped from behind the shoulder of forty six steer calves in January. The calves were approximately 9 months old

and were all from the same herd of range Hereford cows. They were grouped according to their respective sires which were; three Charolais, two Hereford and a group sired by a random group of Aberdeen Angus bulls. Densities, diameters and lengths were determined for each hair sample. The mean density of hairs per square centimeter for groups and the range for individuals within groups are as follows; Charolais x Hereford 1624 (683 to 2327), Hereford 1885 (1180 to 2836), Aberdeen Angus x Hereford 1929 (1123 to 3077). More than 90% of the hairs measured were 0.032 mm. or less in diameter and the distribution of fine and course hairs was similar for all groups. More than 95% of the hairs measured were five centimeters or less in length and again the distribution was similar for all groups. There was sufficient differences between sire groups for the total hair coat to suggest a possible relationship with winter hardiness.

35. CHANGES IN LENGTH AND WIDTH OF CANNON BONE AS RELATED TO AVERAGE DAILY GAIN IN BEEF CALVES. W. Combs, G. E. Nelms, and P. O. Stratton, *University of Wyoming, Laramie.*

The fore-cannon bones of 205 Hereford, Angus and Shorthorn bull and heifer calves dropped in 1957, 1958, and 1959, were x-rayed at birth, weaning and approximately one year of age. The average daily gains in body weight, cannon bone length and cannon width were studied for the periods of birth to weaning, weaning to one year and birth to one year. Averages of yearly mean daily gains in body weight from birth to one year between breeds within sexes were: H 1.85, A 1.86, S 1.96 lb.; heifers: H 1.56, A 1.58, S 1.57 lb. In both sexes, Herefords consistently weaned at lighter weights but made compensatory growth postweaning. The ratios of preweaning to postweaning gain in body weight were: bulls: H 0.70:1, A 0.87:1, S 0.76:1; heifers: H 0.83:1, A 1:1, S 1:1. Although the Angus were born with shorter, narrower cannon bones, the averages of yearly mean changes in cannon bone length from birth to one year were similar between breeds within sexes: bull: H 0.0116, A 0.0112, S 0.0113 cm.; heifers: H 0.0110, A 0.0111, S 0.0107 cm. Preweaning to postweaning changes in cannon bone length ratios were: bulls: H 2.1:1, A 2.9:1, S 2.75:1; heifers: H 1.9:1, A 2.7:1, S 2.2:1. Averages of yearly mean daily changes in cannon bone width between breeds within sexes were: bulls: H 0.0040, A 0.0041, S 0.0034 cm.; heifers: H 0.0033, A 0.0032, S 0.0028 cm. Ratios of preweaning to postweaning increase in cannon width were: bulls: H 0.8:1, A 1.1:1, S 0.8:1; heifers: H 0.9:1, A 1.3:1, S 0.9:1. Correlation coefficients between gains in body weight, cannon length and cannon widths were 0.52 or lower and generally non-significant. Correlations between periods within traits were generally higher and significant.

36. PHENOTYPIC CORRELATIONS BETWEEN CONFORMATION SCORES AND LIVEWEIGHTS AT 8, 12, AND 20 MONTHS OF AGE AND RATE OF GAIN OF BEEF CATTLE. Estel H. Cobb, Oliver Wayman, and Valentino Arganosa, *University of Hawaii, Honolulu.*

Data from four ranches involving 220 bulls and 374 heifers were analyzed for the interrelationships among weaning (8 months of age) weight, daily gain from birth to weaning, weaning conformation score, 12-month weight, daily gain from birth to 12 months, 12-month conformation score, 20-month weight, daily gain from birth to 20 months, 20-month conformation score, and daily gain from weaning to 20 months. Correlations were computed separately for bulls and heifers using the pooled sum of squares and cross-products within year, sire, and ranch. Correlations between traits for heifers and bulls were similar. Positive correlations of 0.5 or higher were obtained between weaning weight, 12-month weight, 20-month weight, daily gain from birth to weaning, daily gain from birth to 12 months, and daily gain from birth to 20 months. Positive correlations of 0.5 or higher were obtained between weights and conformation scores taken at the same age. Slightly lower positive correlations were obtained between weights and conformation scores taken at different ages. Negative correlations of —0.2 to —0.5 were obtained between weaning weight or daily gain from birth to weaning and rate of gain from weaning to 20 months.

37. COMPARISON OF TWO METHODS OF ADJUSTING WEANING WEIGHTS OF CALVES FOR AGE OF DAM AND SEX OF CALF. C. C. O'Mary and Don Ament, *Washington State University, Pullman.*

Ninety-nine records from twenty-seven Angus cows were used to compare two methods of adjusting calves' weaning weights for age of dam and sex of calf. Age of dam ranged from two through ten years inclusive. Weaning weights were adjusted to 180 days as follows:

$$\frac{\text{(actual weaning weight-birth weight)}}{\text{age in days}} \times 180 + \text{birth}$$

weight. The two methods for adjusting calves' weights for age of dam were (1) the addition of 20, 10, 5, 0, 5 and 10% to the weights of calves from 2, 3, 4, 5–8, 9 and 10-year-old cows respectively, and (2) the addition of 75, 44, 19, 7 and 0 lb. to the weights of calves from 2, 3, 4, 5 and 6–10-year-old cows respectively. For both methods, after adjusting for age of dam, 25 lb. was added for heifers and 15 lb. subtracted for bulls. Method (2) resulted in less within cow variation than method (1). Correlation coefficients for weight of calf and age of dam were unadjusted, 0.93; method (1), 0.61; and method (2), —0.004. Rank of cow based on average weaning weight of calves remained essentially the same for unadjusted and adjusted weights. Both methods resulted in greater average weaning weights from 2- than 3-year-old cows. Thus the data suggest method (2) as the more reliable for removing variation in weaning weights due to age of dam.

38. LEVELS OF CERTAIN BLOOD ENZYMES AND CHOLESTEROL OF STEERS AS RELATED TO MEAT QUALITY. A. F. Anglemier, W. K. Johnston, Jr., and A. T. Ralston, *Oregon State University, Corvallis.*

Blood samples were taken from 11 steers at 2-week intervals during the 3-month period preceding their slaughter. Rib roasts were obtained from the carcasses and were cooked via standard procedures and judged by a trained taste panel. The panel results showed that the roasts from seven animals were rated about 1 point higher on the .7 point hedonic

scale for tenderness and one-half point higher on fineness of texture than roasts of the other four animals. Using this same division, the average values (seven different samplings) of the blood analyses of these animals show the following blood pattern trends: animals producing the more tender and finer textured meat had a 17.8% lower alkaline: acid phospatase ratio; 14.7% lower oxalacetic: pyrunic transaminase ratio; 8.5% lower oxalacetic transaminase activity; 10.5% lower amylase levels; and 13% lower levels of both total and free cholesterol. Lean tissue analysis of the meat of the more tender animals showed a 24% higher level of alkaline phosphatase activity than that of the less tender animals. Furthermore, a correlation coefficient of 0.78 was noted between alkaline phosphatase activity of the lean tissue and tenderness scores.

39. A COMPARISON OF THE ORGANOLEPTIC SCORES AND COOKING LOSSES OF FRESH FROZEN AND FROZEN STORED BEEF RIB ROASTS AS AFFECTED BY IMPLANTED HORMONES. W. H. Kennick, D. C. England and Lois A. Sather, *Oregon Agricultural Experiment Station, Corvallis.*

Twenty-four steers calves in each of three lots were implanted with hormones on day 1, day 90, and day 190 on feed as follows: Lot I, control 0–0–0; Lot II, 18–18–18 mg. DES; Lot III, Synovex. The steers were slaughtered after 270 days on feed, at which time the 10–11th rib roast was obtained from each side. The roasts were aged seven days, wrapped in aluminum foil and locker wrap, sharp frozen at 20° F. and stored at 0° F. Cooking tests including percent drip, percent loss, and minutes per pound to cook, and organoleptic tests including aroma, tenderness, texture, flavor of lean, juiciness, flavor of fat and overall score by a trained taste panel were run on the fresh stored roasts as soon as all samples were available and on the matching ribs after 10 months of storage at 0° F. In the fresh frozen samples, there was a small but significantly higher aroma in the roasts from steers receiving hormones than in the control roasts. After ten months storage, the DES treated roasts had a stronger flavor of fat than control roasts. The roasts from hormone treated steers required fewer minutes per pound to cook than did control roasts. There were no other significant differences. These data indicate that there is no detrimental effect during the frozen storage of beef as a result of implanted DES or Synovex.

40. THE EFFECT OF IMPLANTED HORMONES ON COOKING LOSSES AND ORGANOLEPTIC SCORES OF FRESH FROZEN BEEF RIB ROASTS. W. H. Kennick, D. C. England and Lois A. Sather, *Oregon Agricultural Experiment Station, Corvallis.*

This experiment was conducted from 1957 through 1960, inclusive. The steers from which samples were obtained included: (1) control, no hormone implant; (2) Diethylstilbestrol (DES) at several dosages and at different time frequencies; (3) Synovex; and, (4) Testosterone and DES alternately. The steers were put on feed as calves in the fall and fed for approximately 270 days. At slaughter, the 10–11th rib from the left side of each carcass was obtained, aged seven days, wrapped in aluminum foil and locker paper, sharp frozen, and held until all samples for any one year were collected. In 1957 there were six lots of 15 head each; in 1958, 6 lots of 6; in 1959, 3 lots of 24; and in 1960, 3 lots of 18. Cooking tests were conducted for percent drip, percent weight loss, and minutes per pound to cook. Organoleptic tests were conducted with a trained taste panel for aroma, flavor of lean, flavor of fat, tenderness, texture, juiciness and overall score. In 1957, there was a small, but significant, difference among DES implanted samples in aroma and flavor of fat. In 1959 the control samples had less aroma than DES or Synovex treated samples but were more juicy than the DES group. In 1960 the control group had a higher flavor of lean and lower flavor of fat than the DES group. There were no other significant differences and those differences which were demonstrated were so small as to have no commercial consequences.

41. FACTORS ASSOCIATED WITH MARBLING IN YEARLING BEEF CARCASSES. G. O. Harwin, H. H. Stonaker and M. H. Hazaleus, *Colorado State University, Fort Collins.*

Feedlot data, body measurements and carcass characteristics on 118 yearling Hereford steers, the progeny of 20 sires, available from an earlier type study conducted at this station (1950), were used to investigate factors influencing marbling score. The steers were individually fed to a constant finish grade of low choice. Characteristics showing the highest simple correlations with marbling were the following: carcass grade (0.46), percent kidney knob (0.39), percent fat (0.36), slaughter age (0.32), percent round (0.31), slaughter weight (0.27), days on feed (0.23), condition score (0.20), and daily gain (0.20). A multiple correlation (R) of 0.50 was found between marbling and 11 observations on the live steers. These were selected on the basis of their correlation with marbling. Standard partial regression coefficients for these variables were: circumference hindquarter (—0.66), heart girth (0.58), daily gain (0.36), slaughter age (0.31), feed efficiency (0.29), wither height (—0.19), slaughter weight (—0.13), slaughter grade (0.09), condition score (0.09), width of body (—0.09), and days on feed (0). An R of 0.59 was found when 11 variables comprising feedlot data, carcass characteristics and a single body measurement (heart girth) were included. Standard partial regression coefficients were: slaughter weight (—0.66), daily gain (0.53), percent kidney knob (0.36), slaughter age (0.27), rib fat thickness (0.20), heart girth (0.18), percent fat (0.11), feed efficiency (0.10), condition score (0.06), days on feed (—0.06) and percent round (0.06). Another analysis including seven independent variables comprising essentially feedlot characteristics yielded an R of 0.48. Intra-class correlations using the predicted values of marbling obtained from the multiple regression analyses (R=0.59) yielded an estimate of heritability for marbling close to zero (h^2=0.05).

42. CORRELATIONS AMONG TASTE PANEL SCORES AND VARIOUS OTHER MEASURES USED IN BEEF CARCASS EVALUATION. Estel H. Cobb, Mabel Walker, and Kenneth K. Otagaki, *Department of Animal Science and Department of Foods and Nutrition, University of Hawaii, Honolulu.*

Data from the 9–10–11th and 12th rib cuts from 60 carcasses were used in this study. Correlations

among taste panel scores for tenderness, juiciness, flavor and general acceptability on the cooked 9–10–11th rib cut and certain other measures of beef quality were obtained. Good agreement was obtained between the taste panel scores and the Warner-Bratzler shear test for tenderness (r=—.76). Positive correlations (0.5 to 0.9) were obtained among taste panel scores for tenderness, juiciness, flavor, and general acceptability. Low and non-significant correlations were obtained between tenderness and the amount of marbling, as measured by % ether extract in the rib eye muscle or marbling score, when the effect of grade has been removed. All the correlations between scores for color of external fat and color of the rib eye muscle and the taste panel scores for tenderness, juiciness, and flavor were small and not statistically significant.

42a. CROOKED CALF DISEASE. Wayne Binns, Lynn F. James and James L. Shupe, *Animal Disease and Parasite Research Division, A.R.S., U.S.D.A., Logan, Utah.*

The etiology of a congenital deformity in calves, commonly called "crooked calves", was studied in a feeding trial with seven Holstein heifers 18 to 21 months of age which were bred by artificial insemination. Each animal was started on the experiment at various periods of their gestation period ranging from the first day after breeding to the 71st day of gestation and continuing daily from 39 to 120 days. Treatments consisted of lupine and/or lead fed daily through a plastic rumen fistula apparatus with a basal ration of third crop alfalfa hay, group salt, and water at free choice. Two animals fed lupine and lead gave birth to full-term crooked calves while three of the heifers fed lupine alone gave birth to full-term normal calves. Two animals were fed lead only, of which, one gave birth to a full-term normal calf, while the second heifer died of lead poisoning on the 129th day of gestation and on necropsy examination the fetus appeared normal.

43. THE RELIABILITY OF THE LIVER BIOPSY TECHNIQUE FOR ESTIMATING HEPATIC VITAMIN A STORAGE. T. A. Anderson, R. E. Taylor, R. H. Diver, Farris Hubbert, Jr., and W. H. Hale, *University of Arizona, Tucson.*

Ninety-six livers from cattle and sheep with a wide range of vitamin A storage were analyzed to determine the variation in vitamin A content which might occur in sampling 4 different sites in each liver. These values were used to place confidence limits upon the accuracy of a liver sample obtained by the liver biopsy technique. The coefficient of variation was highest for those livers with either very high or very low vitamin A stores and lowest when the hepatic vitamin A storage was in the normal range. Some significant differences ($P<0.01$) in site variation were noted when the livers were grouped according to previous treatment, with the caudate and ventral lobes showing the lowest vitamin A stores. Throughout the range of vitamin A storage studied, it was estimated that the actual hepatic vitamin A storage would not vary more than $\pm 20\%$ from that of the sample obtained by a liver biopsy ($P<0.05$) if the hepatic vitamin A level was under 24 mcg./gm. fresh liver and less than $\pm 7\%$ if the liver storage range was between 40–160 mcg./gm. ($P<0.05$).

44. COBALT BULLETS FOR STEERS GRAZED ON NATIVE RANGE AND FOR WINTERING RANGE EWES. O. O. Thomas, J. L. Van Horn, J. R. Quesenberry, and Claude Windecker, *Montana Agricultural Experiment Station, Bozeman, and U. S. Range Livestock Experiment Station, Miles City.*

Cobalt bullets were used in two tests with yearling steers and with range ewes. In test 1, 90 yearling Hereford steers were divided into three groups according to weight and genetic background and were grazed on native range at the U. S. Range Livestock Experiment Station from May 18, 1960 until July 13, 1960—a period of 54 days. Lack of rain forced the termination of the trial. Group 1 steers were given a cobalt bullet at the start of the experiment and gained an average of 150 lb. during the grazing period for an average daily gain of 2.68 lb.; Group 2 steers were given a 12 mg. stilbestrol implant and gained 162 lb. for an average daily gain of 2.89 lb.; Group 3 steers served as controls and they gained 147 lb. for an average daily gain of 2.63 lb. In trial 2, 38 yearling Hereford steers were grazed together on native range in Northeastern Montana from June 15, 1960 to August 22, 1960. Cobalt bullets were given to 20 steers and 18 steers served as controls. The steers receiving the cobalt bullet gained an average of 95 lb. during the 68-day period for an average daily gain of 1.40 lb. The control steers gained 112 lb. for an average daily gain of 1.65 lb. In a trial with range ewes, cobalt bullets were given to one-half of a group of 66 Columbia ewes on December 17, 1959. Weights taken on December 21, 1960 indicated a slight gain for the cobalt-treated ewes. Control ewes produced more lambs with a greater birth and weaning weight. Cobalt-treated ewes produced a 0.2 lb. heavier fleece. A trial with 32 ewe lambs in which one-half were given a cobalt bullet showed no advantage for the cobalt treated ewes in terms of increased weight gain; however, cobalt-treated ewe lambs did produce 0.1 lb. greater fleece weight.

45. THE EFFECT OF ALTITUDE STRESS ON ORGAN AND TISSUE DEVELOPMENT AND HEMOGLOBIN FORMATION. Charles W. Mayfield and Lloyd E. Washburn, *Colorado State University, Fort Collins.*

Cattle, sheep and rats were subjected to altitudes ranging from 3,500 to 10,300 feet above sea level. Blood samples were obtained from the cattle and sheep, and rats were sacrificed at certain periods coinciding closely with principal seasonal changes. Growth rates of rats having up to ten weeks exposure to these elevations were depressed by increasing altitude as well as by fluctuating environmental temperature. Hypertrophy of rat adrenal, kidney and liver was observed in animals at altitudes of 8,000 and 10,300 feet, but the heart showed increase in weight only at 10,300 feet. Humerus and femur lengths increased with increasing altitude. Retention of the thymus in female rats and marked degenerative changes of the gonads in male rats occurred at the higher elevations. Seasonal changes in hemoglobin concentration, apparently not related to dietary iron content, were observed in all animals. Shifts in iron and color density values indicated also a seasonal variation in composition of the hemoglobin molecule, especially in animals subjected to extreme changes in altitude.

46. COMPARATIVE IN VITRO DIGESTIBILITY OF SOME MAJOR CONSTITUENTS OF THE SUMMER DIET OF RANGE SHEEP. Kenneth R. Frederiksen and Lloyd E. Washburn, *Colorado State University, Fort Collins.*

Ten range forage species including slender wheatgrass, mountain bromegrass, sedgegrass, wild aster, wild dandelion, sticky weed, wild carrot, lupine, sweet anis and one-flowered sunflower were fermented in vitro with buffered sheep rumen inoculum. Proximate analyses conducted before and after fermentation showed the following minimal-maximal ranges in decline of constituents: dry matter, 30.36–52.06%; crude fiber, 5.87–10.02%; and, nitrogen free extract, 23.82–49.63%. Ether extract was observed to increase during fermentation for all species except the one-flowered sunflower. No consistent relationship was found between gas and volatile fatty acid production.

47. INTERACTIONS OF NITRITE, ALPHA-TOCOPHEROL AND TAPAZOLE UPON THE VITAMIN A NUTRITION OF LAMBS FED "HIGH NITRATE" SILAGE. E. E. Hatfield, G. S. Smith, A. L. Neumann, R. M. Forbes, U. S. Garrigus and O. B. Ross, *University of Illinois, Urbana.*

Thirty-two feeder lambs were fed for 60 days a basal ration consisting of three pounds of "high nitrate" corn silage (1.0% KNO_3 equivalent, dry basis) and one pound of concentrate (85% ground corn and 15% soybean meal) in a 2 x 2 x 2 factorial trial which involved the following treatments: (a) added nitrite (2.7% of ration, dry basis, as KNO_2 equivalent); (b) added vitamin E (120 mg. alpha-tocopherol acetate per day); and (c) thyroid inhibitor, "Tapazole" (100 mg. 1-methyl-2-mercaptoimidazole per day). Four other lambs received a comparable ration containing "normal" corn silage. Weight gains were low in all "high nitrate" treatment groups, and did not differ significantly among groups. Plasma vitamin A values did not differ significantly among groups of lambs fed "high nitrate" silage; however, all were decreased below values for lambs fed "normal" silage (17 vs. 59 mcg. %; $P<.001$). Liver stores of vitamin A were lowered in all groups fed "high nitrate" vs. "normal" silage (698 vs. 1331 mcg. vitamin A per liver per kg. body wt.; $P<.001$). The interaction of effects of added nitrate x alpha-tocopherol x Tapazole upon liver contents of vitamin A was significant ($P<.05$). Treatments and corresponding means of vitamin A values for plasma (mcg. %) and liver (mcg. per liver per kg. body wt.) are: *"normal" silage:* 59, 1331; "high nitrate" silage: $-NO_3-E-T$: 17, 630; $-NO_3+E-T$: 23, 930; $-NO_3-E+T$: 18, 608; $-NO_3+E+T$: 14, 700; $+NO_3-E-T$: 13, 877; $+NO_3+E-T$: 22, 622; $+NO_3-E+T$: 13, 437; $+NO_3+E+T$: 14, 739. Serum calcium and magnesium values for all animals were within the range for normal values.

48. THE INFLUENCE OF ENERGY AND PROTEIN LEVELS ON FEED UTILIZATION BY PREGNANT EWES. Milo L. Dew, J. E. Butcher, and L. E. Harris, *Utah State University, Logan.*

Twelve Rambouillet ewes in the last one-third of pregnancy were allotted to four feed treatments consisting of a factorial arrangement of two levels of protein 47(p) and 94(P) gm. per ewe per day and two levels of digestible energy 1.5(e) and 3.0(E) therms. Lignin was adjusted to a common intake of 45 grams per sheep per day. Dry matter intake varied among treatments although individual sheep were on constant daily intake. The influence of treatment on apparent digestibility of energy was highly significant with the depressing effect of high energy and low protein being the major factor. The average percentages of apparent energy digestibilities for the treatments were EP:63, EP:53, eP:62, and ep:58. Dry matter and organic matter digestibilities followed a similar pattern. Differences in apparent digestibilities of protein (EP:43, Ep:28, ep:75, ep:40) were also highly significant. On a total protein intake basis these differences appeared to be associated with the unbalance of energy and protein, but because of the variation in dry matter intake the percentage protein in the diets (EP:8.9, Ep:5.2, eP:17.7, ep:8.0) varied and the apparent digestibility of protein was highly related ($r=0.97$) to these dietary percentages. Daily nitrogen balance in grams (EP+2.6, Ep—0, eP+1.5, ep—1.0) did not follow the apparent protein digestibility as the low energy-high protein diet evidently required some of the protein as an energy source. Apparent digestibility of lignin (EP+5, Ep+5, eP+5, ep—3) indicated a significant depression due to low protein and low energy. This indicates caution in the use of lignin as an indicator material.

49. EFFECT OF LEVEL OF ZINC BACITRACIN UPON WINTER WEIGHT GAINS OF HEREFORD HEIFERS AND RAM LAMBS. O. O. Thomas and J. L. Van Horn, *Montana Agricultural Experiment Station, Bozeman.*

Hereford heifers were used to evaluate zinc bacitracin in a wintering ration and ram lambs were used as experimental animals in a fattening trial. In two wintering trials, four lots of Hereford heifers were given a full feed of alfalfa hay, 1 lb. of barley and 1 lb. of a grain pellet which furnished 0, 40, 80, or 120 mg. of zinc bacitracin per day. In trial 1, the 300 heifers were started on feed on December 12, 1959 and were weighed off the experiment on March 21, 1960. Lot numbers, level of zinc bacitracin, and average daily gains made during the trial are as follows: Lot 1, 0, 1.27 lb.; Lot 2, 40 mg., 1.28 lb.; Lot 3, 80 mg., 1.36 lb.; Lot 4, 120 mg., 1.38 lb. In the second trial with about 200 heifers, the same procedure was followed. They were started on experiment on January 3, 1961. Lot number, level of zinc bacitracin, and average daily gain made to April 7, 1961 are as follows: Lot 1, 0, 1.45 lb.; Lot 2, 40 mg., 1.48 lb.; Lot 3, 80 mg., 1.65 lb.; Lot 4, 120 mg., 1.68 lb. Two trials were conducted with ram lambs. In both trials they were self-fed a completely pelleted ration containing 15% each of barley, oats, and dried molasses beet pulp, 10% molasses, and 45% sun-cured alfalfa. Zinc bacitracin was added to provide 0, 5, or 10 mg. per lb. of the pellet. In trial 1, three lots of ram lambs of Rambouillet breeding averaging 72 lb. were put on experiment on October 19, 1959 and fed until December 31, 1959. Lot number, zinc bacitracin in mg. per lb. and average daily gains are as follows: Lot 1, 0, 0.48 lb.; Lot 2, 5, 0.46 lb.; Lot 3, 10, 0.52 lb. In trial 2, rams averaged 166 lb. and were fed from January 4 until March 2, 1961. Lot number, mg. of zinc

bacitracin and average daily gains are as follows: Lot 1, 0, 0.36 lb.; Lot 2, 5, 0.35 lb.; Lot 3, 10, 0.38 lb. Three lambs in lot 1 and 2 lambs in lot 2 had digestive disorders during the trial.

50. EVALUATION OF DIAMMONIUM PHOSPHATE AS A SOURCE OF NITROGEN FOR LAMBS. E. L. Russell, W. H. Hale, and Farris Hubbert, Jr., *University of Arizona, Tucson.*

Lambs were given various levels of urea and diammonium phosphate (DAP) by stomach tube. The toxicity of the two compounds on a nitrogen equivalent basis was compared. Toxicity of urea was noted at 15 gms./100 lb. body weight and increased sharply up to 30 gms./100 lb. body weight. No toxicity of DAP was observed up to 40 gm. urea equivalent/100 lb. body weight. One lamb survived a dose of DAP equivalent to 75 gm. urea. DAP was toxic when infused directly into the rumen at a level equivalent to 40 gm. urea/100 lb. body weight. An increase in rumen pH from 6.8 to 8.1 occurred within one-half hour after administration of urea. An equivalent amount of DAP caused an increase from 7.0 to 7.2 in the same time interval. Average maximum blood NH_3N following urea dosage was 42.0 mcg./100 ml./gm. urea equivalent/100 lb. body weight for 21 lambs. Average maximum blood NH_3N was 17.6 mcg./100 ml./gm. urea equivalent/100 lb. body weight for 26 lambs receiving DAP, a highly significant difference. Twenty-four hour urine collections following equivalent doses of urea and DAP showed no difference in urinary N excretion between lambs receiving the two compounds. Nitrogen balance studies were conducted with lambs maintained on rations in which 30% of the nitrogen was supplied as urea or DAP. No significant difference in nitrogen retention was noted between lambs receiving the two compounds.

51. EFFECT ON LAMB GROWTH OF HORMONAL IMPLANTS AND SUPPLEMENTAL COBALT. W. E. Howell, *Animal Husbandry Dept., University of Saskatchewan, Saskatoon, Sask., Canada.*

Two hundred and twenty-seven wether lambs were assigned to four treatment groups: control; those receiving orally one 5 gm. sustained release pill containing 90% cobaltic oxide; those receiving two pellets subcutaneously in the ear, each containing 2.5 mg. estradiol benzoate and 25 mg. progesterone; and those receiving both the cobalt and the hormonal pellets. One hundred and seventeen female lambs were assigned to two groups, control and cobalt treated. The lambs were pastured with their dams and given access to a creep of whole oats and a standard mineral mix. Weights of all lambs were obtained at two-week intervals throughout the test period of 12 weeks. There were no significant differences in growth response in wether lambs treated with cobalt or hormonal pellets or the combination nor were there differences in the response of females in either total gains or period gains to the oral administration of the cobalt pellet. Highly significant differences were obtained between growth periods for both males and females independent of any treatment effect. This is most likely a reflection of the influence of grazing and weather conditions on maternal effect. It would appear from this trial that no advantage is to be gained by the administration of cobalt in excess of that provided in standard cobaltized salt offered free choice to lambs. Nor is there justification under the conditions of this experiment for the administration of estradiol-progesterone implants to suckling lambs as a growth stimulant.

52. REPRODUCTIVE PERFORMANCE OF EWES PASTURED ON DIFFERENT SEQUENCES OF ALFALFA AND WHEATGRASS DURING THE BREEDING SEASON. Darrell H. Matthews and W. C. Foote, *Utah State University, Logan.*

In 1958–59 (432) and in 1959–60 (242) ewes (Rambouillet, Columbia and Targhee) were separated into four groups and pastured during a prebreeding period (21 days beginning October 12–13) and a breeding period (28 days) on alfalfa or wheatgrass in pasture sequences as follows: alfalfa-alfalfa, alfalfa-wheatgrass, wheatgrass-alfalfa and wheatgrass-wheatgrass. Ewes pastured on alfalfa only in 1958–59 had significantly higher percentage lambs born to ewes bred (163) than ewes in other pasture sequences (138, 135, 129, respectively). Differences in lambing percent between these groups in 1959–60 were not significant, but were consistent with the previous year's work (160, 144, 150, 132 respectively). Percent ewes lambing did not differ for the pasture sequence groups either year (100, 95, 92, 95, respectively, for 1958–59; 93, 97, 96, 97, respectively, for 1959–60). Data do not indicate differences in conception date for ewes on the different pasture sequences. Body weight gains were not consistent in regard to pasture or year. Prebreeding gains for the pasture sequence groups for 1958–59 were 10.9, 11.5, 9.4, 9.7 lb., respectively, and breeding gains were 1.6, 0.5, 3.7, 2.4 lb., respectively. Gains for the same periods in 1959–60 were 3.8, 1.2, 5.1, 3.8 lb. and 3.1, 2.6, —2.3, 4.4 lb., respectively. Significant differences were found among pasture sequence gains during the breeding period each year and total gains (sum of both periods) in 1959–60. Significant differences occurred between gains on alfalfa-alfalfa *vs.* wheatgrass-wheatgrass sequence in the prebreeding period for 1958–59 only. Data indicate that alfalfa pasture increases percentage lamb crop when compared to wheatgrass without additional increase in total body weight gains.

53. THE EFFECT OF PLANT ESTROGENS ON HISTOLOGY OF SEMINAL VESICLES IN SHEEP. W. D. Noteboom, F. L. Hisaw, Jr., C. W. Fox and J. E. Oldfield, *Oregon State University, Corvallis.*

Comparison of effects of naturally-occurring plant estrogens and implanted diethylstilbestrol (DES) has been made with sheep. Three lots of Rambouillet wether lambs were fed rations containing 65% pelleted alfalfa meal which tested 20, 110 and 200 parts per million of coumestrol. In addition, two lots receiving the high and low potency meals were implanted with 3 mgm. DES. The length of the trial was 11 weeks. Analysis of seminal vesicle weights revealed significant differences due to DES and plant estrogen treatment. Two hundred ppm coumestrol in alfalfa meal caused almost as much increase in weight as a 3 mgm. DES implant. Combination of 200 ppm coumestrol and DES implant resulted in an additive effect on seminal vesicle weights.

Histological studies revealed that plant estrogens

caused increased proliferation of the fibrous stroma similar to that caused by DES. There were also indications of changes in the nuclei of the epithelium of the lumen. Evidence of possible secretory activity of the epithelial cells from animals on the high estrogen meal was revealed by a slight staining of the cytoplasm.

Proliferation of the stroma of implanted animals on the high estrogen diet was sufficiently great that to cause disruption of the epithelium in places.

54. THE INFLUENCE OF ALTERNATE DAY WATERING ON FEED AND WATER CONSUMPTION OF SHEEP MAINTAINED UNDER TWO TEMPERATURES. Sung S. Choi and J. E. Butcher, *Utah State University, Logan.*

Twenty-four sheep were paired and divided into two groups. One group was maintained in an open barn where the temperatures fluctuated between 20°–40° F. and the other group was maintained in a heated building at 70–78° F. All were individually fed and watered. When watered once daily and fed chopped meadow hay free choice the average feed consumption of both groups was 4.2 lb. per day. The group at the lower temperature consumed 8.7 lb. of water as compared to 12.5 lb. for the high temperature group. During a 40-day period of watering these sheep on alternate days, the feed consumption was reduced to 3.3 lb. per day for the sheep in the cool barn as compared to 2.7 lb. for the sheep in the warmer room. The average water consumption was 5.6 lb. per day in the cool location and 7.4 lb. per day in the warm location. The differences in both feed and water consumption were highly significant between locations. These differences indicate a definite temperature stress. All sheep had a body weight loss after the initiation of the alternate day watering, however after 40 days the sheep in the cool temperature had regained this loss and the sheep in the warm temperature were within 5 lb. of the initial weight. These data indicate that watering sheep on alternate days may be an acceptable management practice during periods of cool temperature (below 40° F.) or as an emergency measure for temperatures up to 78° F.

55. EFFECTS OF FEED AND LENGTH OF FLUSHING PERIOD ON LAMB PRODUCTION IN RANGE EWES. C. V. Hulet, R. L. Blackwell, S. K. Ercanbrack, D. A. Price and R. D. Humphrey, *U. S. Sheep Experiment Station, Dubois, Idaho.*

Approximately 1200 Columbia and Targhee ewes (1957, '58 & '59) were randomized within age and breeding pen into the following treatments: (1) control on native, sagebrush-grass pasture 17 days prior to breeding, on native grass hay in drylot during 34 day breeding season, (2) another control on grass hay for entire period, (3) treatment 1 plus oats (0.7 lb./head/day) until breeding, (4) treatment 2 plus oats until breeding, (5) treatment 1 plus oats up to the 18th day of breeding, (6) treatment 2 plus oats up to the 18th day of breeding, (7) treatment 1 plus oats over entire treatment period, (8) treatment 2 plus oats over entire period. An identical experiment using 1 lb. alfalta pellets in lieu of oats was conducted on a comparable group of ewes. Oat supplementation had a significant effect in mature ewes on number of live lambs born ($P<.10$), pounds live lamb born ($P<.10$) and pounds lamb weaned ($P\cong.06$). Treatment means were 1.28, 1.25, 1.45, 1.41, 1.49, 1.40, 1.42 and 1.28 for numbers of live lambs born, 13.5, 12.5, 15.0, 14.7, 15.0, 14.5, 14.5 and 13.3 lb. live lamb born and 88.7, 80.3, 98.9, 95.6, 95.1, 89.5, 93.2 and 88.0 for lb. of lamb weaned of ewes present at lambing for the eight treatments, respectively. Mean separation analyses (.05 level of probability) support in general the conclusion that a short flushing period (17 days) immediately prior to breeding increased lamb production over the controls. Extending this period an additional 17 days during breeding produced no further increase in production but increased costs. A further extension of 17 days caused an apparent production decline from that of the shorter periods. Ewes on native grass hay for 17 days prior to breeding had lower lamb production than those on dry, native pasture. Alfalfa pellets had an apparent but nonsignificant flushing effect on lamb production in mature ewes. Neither oats nor alfalfa pellets had significant flushing effects on two-year-old ewes. Change in body weight during treatment was not significantly correlated with lamb production.

56. A FERTILITY INDEX FOR RAMS. C. V. Hulet and S. K. Ercanbrack, *U. S. Sheep Experiment Station, Dubois, Idaho.*

Semen observations on thirty-nine Rambouillet, Targhee and Columbia rams representing the entire range of semen quality were used to derive indexes of fertility. At least two consecutive, naturally ejaculated semen-samples were obtained from each ram prior to breeding. Each ram was pen mated for one heat period to five potentially fertile ewes. Fertility was determined at 25 days of gestation by examining the uteri for embryos at autopsy. All possible simple correlations were calculated among 13 semen traits, inbreeding coefficient, type of birth and rearing, age of ram's dam, face-cover score and fertility. Using multiple regression methods and including ultimately only those traits making worth-while contributions to the multiple correlation, the following fertility indexes were developed: Index A= 174.4 −17.19 (pH) +0.28 (% live normal) −0.08 (% abnormal) −0.2 (% abnormal necks). Index B= 217.0 −4.38 (motility score) −18.89 (pH) −0.19 (% abnormal) −0.14 (% abnormal necks). Percent values pertain to spermatozoa. The standard partial regressions for traits used in Index A were $b'_{pH} = -.255$, $b'_{\%L.N.} = 0.293$, $b'_{\%Abn.} = -.082$, and $b'_{\%A.N.} = -.210$ and in Index B were $b'_{M.S.} = -.210$, $b'_{pH} = -.240$, $b'_{\%Abn.} = -.202$, and $b'_{\%A.N.} = -.151$. The multiple correlations and standard errors of estimate for the two indexes were 0.74 and 0.73, and 21.3% and 21.3%, respectively. The correlations between these indexes and the actual fertility of all semen tested rams (136 head) used in 1959 were 0.76 and 0.73, respectively. These compare with a correlation of −.49 between the semen score previously used (based primarily on independent scoring levels) and fertility.

57. A COMPARISON OF INDEX SELECTION WITH SINGLE TRAIT SELECTION IN SHEEP. L. T. Twombly, T. M. Sutherland, A. L. Esplin and H. H. Stonaker, *Colorado State University, Fort Collins.*

A study of three selection methods was conducted on lamb weights and staple length at weaning. These

lambs were raised from Columbia-Rambouillet ewes and sired by purchased rams which had been visually selected as yearlings. Estimates were made of the environmental factors, namely, year of birth, sex, type of birth and rearing, age of dam, and generation, and the regression of staple length and weaning weight on age. Selection on an index, weighting the staple length and weaning weight traits equally, was actually more effective in changing weaning weight than selection for weaning weight itself and ranked very close in staple length to the group selected solely for staple length. Large variations (as high as 27.6 lb. and 0.83 in.) between years were observed. Males were heavier than females, and singles were heavier than twins raised as singles, twins, and triplets raised as twins. Four- and five-year-old ewes raised the heaviest lambs. Females had longer staple lengths than males, and singles had longer staple lengths than twins raised as singles, twins, and triplets raised as twins. Age of dam had the greatest effect on staple length. Heritability estimates observed were 0.35 for weaning weight, 0.72 for staple length, and 0.33 for index.

58. SELECTION DIFFERENTIALS FOR YEARLING, FINE-WOOL, RANGE EWES. Thomas H. Hall, L. A. Holland and W. D. McFadden, *New Mexico State University, University Park.*

Selection differentials for seven traits were obtained from data on 843 yearling, fine-wool, range ewes. Tandem selection of the top 40% were practiced for four of the seven traits. Selection differentials obtained with selection based on body weight were: Body weight, 8.92 lb.; grease fleece weight, 0.75 lb.; clean fleece weight, 0.35 lb.; staple length, 0.04 in.; density, 0.89 units; visual fineness, 0.12 mu.; and visual crimp ratio, —.02 units. Selection differentials obtained with selection based on grease fleece weight were: Body weight, 4.77 lb.; grease fleece weight, 1.33 lb.; clean fleece weight, 0.45 lb.; staple length, 0.10 lb.; density, —.53 units; visual fineness, 0.29 mu.; and visual crimp ratio, —.08 units. Selection differentials obtained with selection based on clean fleece weight were: Body weight, 5.21 lb.; grease fleece weight, 1.07 lb.; clean fleece weight, 0.58 lb.; staple length, 0.09 in.; density, 1.52 units; visual fineness, 0.32 mu.; and visual crimp ratio, .24 units. Selection differentials obtained with selection based on staple length were: Body weight, 1.13 lb.; grease fleece weight, 0.44 lb.; clean fleece weight, 0.16 lb.; staple length, 0.35 in.; density, —2.73 units, visual fineness, 0.64 mu.; and visual crimp ratio, 0.39 units. Selection differentials calculated using phenotypic correlations, standard deviations and the z/b value for 40% saved agreed well with those calculated from the raw data.

59. PHENOTYPIC CORRELATIONS AMONG FLEECE TRAITS AND BODY WEIGHT OF DEBOUILLET SHEEP. L. A. Holland, and W. D. McFadden. *New Mexico State University, University Park.*

Phenotypic correlations among body weight, staple length, grease fleece weight, clean fleece weight, density, measured fineness, and crimps per inch were computed from data obtained from 286 Debouillet ewes, 21–23 months old and heavy with lamb. Correlations among body weight, staple length, grease fleece weight and clean fleece weight were generally lower than those reported in the literature. Other correlations were similar to those generally reported. Correlations among traits for the 166 ewes which were approved by an inspector for selective registration were different than correlations among traits for the entire group of 286 ewes.

60. PREDICTING CLEAN FLEECE WEIGHTS OF COLORADO FLEECE WITH NEALE'S CLEAN FLEECE WEIGHT DEVICE. Charles W. Nichols and V. B. Swanson, *Colorado State University, Fort Collins.*

Four hundred and fifty fleeces covering a wide range in size and fleece grade and from flocks representing various areas of Colorado were used to test the accuracy of the Neale clean fleece weight device in predicting the clean wool content of Colorado fleeces. Two variations of the device and two different torque wrenches for operating the device were tested. Device readings were taken on the fleeces with combinations of the two devices and wrenches to determine which combination was the most accurate. Correlations between the various device readings taken and actual clean fleece weight, determined by sample scouring, ranged between —0.84 and —0.95. The effects of various environmental conditions on the estimation of clean fleece weight with the Neale device were investigated. Correlations between clean fleece weight and device readings on the same fleeces under different environmental conditions ranged between —0.88 to —0.94. Correlations between clean fleece weight and staple length were 0.43**, between clean fleece weight and fiber diameter 0.14*, and between clean fleece weight and grease fleece weight 0.44**. Conversion tables for predicting clean fleece weights from device readings were prepared by the use of the prediction equation $\text{Log } Y = a + bX$.

61. INTERACTION OF INBREEDING WITH PRODUCTION TRAITS IN SHEEP. Noah England and Ralph Bogart, *Oregon Agricultural Experiment Station, Corvallis.*

Data taken on 321 lambs were used to study the effects of inbreeding on various production traits of the lamb and the interaction of inbreeding of the lamb with its birth weight and rate of gain to weaning. The interactions show that the severity of inbreeding depression varies for different segments of the population. The portions of the flock that had the highest adjusted birth weight—singles and one line—were most adversely affected by inbreeding. The visible differences in inbreeding effects between birth types is most likely due to the inability of the twin to express its genetic potential for birth weight due to environmental restrictions, and therefore increased homozygosis due to inbreeding will not bring about the same relative decrease in birth weights of twin lambs as of single lambs. The difference in inbreeding effects between lines seems to be due to differential action of inbreeding upon differing genotypes. There appears to be distnict thresholds for individual traits so far as inbreeding depression is concerned. Above these thresholds, deleterious effects are noted but below them there are no apparent depressions. Thus, it appears desirable to break inbreeding into discrete classes for a study of this kind since the severity of the inbreeding effects is not necessarily proportional to the intensity of inbreeding.

62. THE INFLUENCE OF VARIOUS LEVELS OF LEVELS OF PROTEIN AND PHOSPHORUS ON THE VOLATILE FATTY ACID COMPOSITION OF THE RUMEN OF SHEEP. Paul V. Fonnesbeck and Lorin E. Harris, *Utah State University, Logan.*

Three levels of protein (7, 9 and 11%) and three levels of phosphorus (0.11, 0.22 and 0.33%) were fed in a factorial arrangement to 18 wether sheep (two replications of nine sheep) while individually fed a continuous diet of coarsely chopped meadow hay. The protein supplement was wheat gluten. The phosphorus supplement was monosodium phosphate. The sheep were fixed with a rumen fistula through which protein and phosphorus supplements were fed and rumen liquor samples were withdrawn. After a 20-day preliminary feeding period rumen samples were taken (before feeding, 3, 6 and 12 hours after feeding). After 3 days of sampling the sheep were reassigned to treatments at random with the restrictions that no sheep receive the same treatment as before received. After a 20-day preliminary feeding period samples were again withdrawn at the same times for 3 days. Samples were analysed for volatile fatty acid (VFA) composition. There was a significant linear increase in formation of acetic, propionic and total VFA due to the protein treatments. There was a highly significant difference in VFA production due to time of sampling. Phosphorus had no significant effects on VFA production. Increasing the nitrogen level 4% with wheat gluten caused approximately a 7% increase in VFA formation.

63. SELECTION OF LAMBS UNDER FARM CONDITIONS. C. M. Bailey, A. B. Chapman, A. L. Pope and L. L. Felts, *University of Wisconsin, Madison.*

Time trends for lambs recorded in the Wisconsin Sheep Improvement Program (WSIP) during the decade 1950 to 1960 indicate that the average merit of lambs improved. An analysis was made of the records of 1855 ewe lambs in flocks which were enrolled in the program for a minimum of 3 years. Heritabilities were estimated within a year, flock, and breed by doubling the multiple regression of offspring on dam, holding certain environmental effects constant. Approximately one-half of the dams were two- and three-year olds. Means and standard deviations for 120-day adjusted weight (lb.), staple length (cm.) and lamb index (overall merit) were: 65.88, 10.29; 4.30, 0.84; and 86.90, 10.72, respectively. Age-of-dam was an important ($P<.01$) source of variation in weaning weight and lamb index. Singles were superior ($P<.01$) to twins raised as twins and to twins raised as singles for 120-day weight and staple length. Selection differentials for ewe lambs were: 1.85, 0.03, and 1.92 for 120-day weight, staple length and lamb index, respectively. Heritability estimates for these three traits were: 0.43, 0.17, and 0.47, respectively. The within-flock regression of mean lamb index on years for flocks which participated in the program for 3 or more years was 0.81.

64. VARIATIONS IN LAMB FAT FROM DIFFERENT AREAS OF THE CARCASS. J. A. Marchello, D. A. Cramer and T. M. Sutherland, *Colorado State University, Fort Collins.*

Due to the possible existence of variation in fat characteristics of fat samples collected from various areas of the carcass a study was conducted to determine its scope. Samples from eight areas were collected from 23 lambs (bung, cod, kidney, leg, loin, neck, rack, shoulder). The lambs represent three different environments. Iodine numbers (IN), melting points (MP), and saponification numbers (SN) of the fat were calculated. Statistical analysis revealed highly significant differences between areas for the three chemical analyses conducted—this was also true for differences between lambs. Averages for the eight areas ranged from a high to a low as follows: IN —46.9 (leg) to 37.4 (kidney), MP —48.5° (kidney) to 42.2° (loin), SN —198.5 (loin) to 196.6 (kidney) with a standard error of ±1.23, ±0.04, ±0.01, respectively. Since the bung area is more adapted to fat sampling than other areas of the carcass, correlation coefficients were calculated to determine the relationship between IN, MP, and SN of bung fat to fat samples from the other seven areas. These r values ranged from 0.95 (leg) to 0.75 (kidney) for IN; 0.82 (loin and rack) to 0.22 (kidney) for MP; 0.69 (cod) to 0.22 (loin and shoulder) for SN. Lamb x area interaction accounted for a large part of the variation in IN and SN (75% and 56%, respectively); however, MP was influenced to a smaller degree (8%).

65. EFFECT OF TEMPERATURE AND SHEARING ON FAT CHARACTERISTICS AND FEEDLOT PERFORMANCE OF LAMBS. D. A. Cramer, J. A. Marchello and T. M. Sutherland, *Colorado State University, Fort Collins.*

Twenty wether lambs were selected from one flock by weight and fed through the coldest part of the winter. The lambs were divided into two groups of ten lambs each with lot I unprotected and lot II housed at 90° F. Five lambs in each lot were shorn twice during the trial. The average total gains for lots I and II were respectively: shorn —42.6, 29.2; unshorn —37.0, 26.0 lb. Lot I and lot II required an average of 8.49 and 10.62 lb. of feed per lb. of gain respectively Samples of fat were collected from the bung and loin areas of all lambs after slaughter and analyzed for iodine number (IN), saponification number (SN) and melting point (MP). The temperature extremes caused a highly significant difference in IP and MP of the fat between groups of lambs but did not greatly alter the SN. On the other hand, shearing produced a highly significant difference only in MP of fat between groups with little effect on IN and SN. Temperature-shearing interaction was non-significant in all three analyses. These results indicate that fatty acid dehydrogenase equilibrium is somewhat dependent on environment and that enzymic control over carbon chain length in lamb fat is independent of environment. In addition 4 lambs were housed in digestion crates and the temperatures of depot fat from several areas of the body were recorded daily for three weeks. The lambs were then slaughtered and fat samples were collected from all areas and analyzed for IN, SN and MP. The gross simple correlations between average fat temperature and IN, SN and MP were —.676, —.437 and 0.822 respectively.

65a. THE USE OF MINERAL SUPPLEMENTS FOR THE PREVENTION OF HALOGETON POISONING IN SHEEP. Lynn F. James and Wayne Binns, *Agricultural Research Service, Logan, Utah.*

Oxalic acid poisoning as it occurs in sheep and cattle is caused by the ingestion of forage high in soluble oxalates. The poisoning is most frequently

encountered in sheep on western range areas from the ingestion of halogeton (*Halogeton glomeratus*). Feeding trials using lethal doses (.55 gms. soluble oxalates per pound of body weight) of halogeton caused an approximate two fold increase of potassium per 100 ml. blood serum. The blood calcium decreased from an average of 7.65 to 0.5 mg. calcium per 100 ml. blood serum. The chloride, magnesium, and sodium content showed no change. Mineral supplements were fed (.62 gms. calcium per .55 gm. soluble oxalate) with a lethal dose of halogeton to sheep to determine if they would give any protection against oxalate poisoning. Bone meal and monosodium phosphate (monosodium phosphate fed to give the same amount of phosphorus as dicalcium phosphate) did not give any protection for halogeton poisoning. The sheep receiving deflorinated rock lived but were unthrifty. The sheep receiving the dicalcium phosphate showed no effects of the halogeton. Calcium carbonate was fed at 0.5 gms. calcium per 0.26 gm. soluble oxalates. Calcium gluconate was (9% calcium) injected intravenously every four hours until death. The calcium gluconate gave no protection. The sheep receiving the calcium carbonate recovered but showed a decrease in blood calcium and an increase in blood urea nitrogen shortly after feeding.

65b. USE OF PROGESTERONE FOR CONTROLLING ESTRUAL BEHAVIOR IN EWES. M. W. Galgan and C. C. O'Mary, *Washington State University, Pullman, Washington.*

Twelve ewes were randomly allotted within breed to three groups of four ewes each (2 Columbias, 2 Hampshires per group). Ewes of Groups 1 were injected with 12.5 mg. progesterone (aqueous suspension) daily for 14 days. Ewes in Group 2 received injections of 25 mg. of progesterone each every other day for seven injections. Ewes of Group 3 received 37.5 mg. of progesterone per injection every third day for 5 injections. One Columbia and one Hampshire ewe of each group received the injections subcutaneously, while each of the other two ewes of the group was injected intramuscularly. Although the numbers were too small for statistical treatment of the data, it is of interest to note that the average time of heat after stopping treatment was 3.5 days for Group 1, 4.5 for Group 2 and 5.2 for Group 3. The Hampshires came into heat 3.7 days and the Columbias 5.2 days after treatment stopped. With subcutaneous injections and intramuscular injections the time of heat was 5.5 and 3.3 days respectively. A fertile ram was turned in with the ewes at the last hormone injection. Only three of the twelve ewes lambed from conception at the first heat period (two on one day and one 2 days later). The other nine lambed from conception at the 2nd heat. The lambing interval was seven days.

66. LOIN EYE AREA, WHOLESALE CUTS, SHOULDER SCORE, GRADES, AND YIELD AS MEASURES OF MEATINESS IN LAMBS. Eugene H. Rupnow, M. W. Galgan and J. A. Richter, *Washington State University, Pullman.*

This program involved 51 animals that were grouped according to breed for testing. There were 21 Columbia, 20 Hampshire, and 10 Southdown lambs in the groups. The Columbias and Hampshires represented a cross section of offspring of two sires of each breed while the Southdowns were only from one sire. The lambs were slaughtered in August, 1960, chilled for 48 hours and then measurements were taken. There proved to be significant differences in federal grade, conformation score, fat thickness, and dressing percentage. In each of these areas the Southdown was highest with Hampshires next and Columbias lowest. A significant difference was found in loin eye areas as measured from tracings. Hampshires had the largest area, Columbias second, and Southdowns the smallest area. Also the differences in meatiness scores as done from shoulder photographs was found to be significant. In this the Columbias were meatiest, Hampshires next, and Southdowns the fattest. There were no significant differences found in the percentage of the wholesale cuts. The Hampshires did show a slightly higher percentage in the breast, and shank, when compared with the other breeds. Tenderness as determined by Warner-Bratzler Shear machine did not prove significant differences between the breeds.

67. FAT AND PROTEIN RELATIONSHIPS IN RATIONS OF GROWING-FINISHING BACON PIGS. J. P. Bowland and M. S. Kuryvial, *University of Alberta, Edmonton, Alberta, Canada.*

Rate of gain, efficiency of feed utilization and carcass characteristics were studied with 108 pigs fed 9 rations factorially divided to supply 3 levels each of energy and protein. Apparent energy and nitrogen digestibility and nitrogen retention were determined using weanling rats and 15 and 90 lb. pigs. The energy levels of the predominantly wheat, soybean oil meal, fishmeal rations were altered by the addition of 0, 15 or 30% stabilized tallow giving average gross energy levels of 4.0, 4.8 or 5.3 cal./gm. of ration respectively. Protein levels averaged 14, 18 and 22% on an air-dry basis. Energy digestibility was not consistently affected by fat and protein levels in the rations. Nitrogen digestibility and retention were improved by the addition of fat to diets of weanling rats but this was not clearly evident with pigs. In 90 lb. pigs, nitrogen digestibility was significantly increased but retention was decreased as protein levels of the ration increased. In rats and lighter pigs, protein levels had no predictable effect on nitrogen digestibility and retention. The addition of supplemental fat and/or increased protein levels improved the rate of gain and efficiency of feed utilization in pigs from weaning at 3 weeks of age to market weight. Increased protein levels in the diets of rats had a similar effect but supplemental fat improved only efficiency of feed utilization. Based on Canadian R.O.P. standards, carcass quality of pigs fed supplemental fat was reduced mainly because of increased carcass fat.

68. GRASS-LEGUME SILAGE FOR GROWING-FATTENING SWINE. D. M. Bowden, *Canada Department of Agriculture, Agassiz, British Columbia.*

Two experiments were conducted to study feeding silage free-choice to pigs receiving concentrate self-fed or restricted. Treatments in Experiment 1: (I) self-fed concentrate; (II) self-fed concentrate plus silage; (III) concentrate at 85% of full-feed plus silage; (IV) concentrate at 70% of full-feed plus silage. Sixteen pigs were fed individually on each treatment. Pigs self-fed concentrate consumed .09 lb. of silage dry matter per day, those restricted to 85% consumed .36 lb. and those restricted to 70% consumed .55 lb. In Experiment 2, molasses was added to the silage at feeding time in an attempt to increase

silage consumption. Treatments were the same as I, II, III of Experiment 1 with molasses added to the silage. Twenty-four pigs were fed individually on each treatment. Pigs in this experiment were fed in two replicates. In one replicate the average consumption of silage dry matter was .47 lb. per day with self-fed concentrate and 1.36 lb. with restricted concentrate. In the other replicate it was .17 lb. for self-fed and .42 lb. for restricted. This difference in consumption of silage was the result of better silage quality in one replicate. Even at the highest levels of silage consumption, growth of pigs on restricted concentrate was slower than those self-fed. In Experiment 1 there were no significant differences in carcass quality or feed efficiency. In Experiment 2 pigs on restricted concentrate produced leaner carcasses on less concentrate. Use of molasses with silage did not affect the consumption of grass-legume silage.

69. THE USE OF STRAW AS A MEANS OF RESTRICTING NUTRIENT INTAKE OF REPRODUCING SOWS. D. W. Blackmore and O. O. Thomas, *Montana Agricultural Experiment Station, Bozeman.*

The purpose of this investigation was to develop a ration which could be self-fed to pregnant swine without deleterious effects. Each of the four rations used was designed to meet the vitamin and mineral requirements of the sows. The only variables in the ration were alfalfa hay, straw and fat. The rations contained: (1) 1500, 0 and 0; (2) 1200, 300 and 0; (3) 900, 600 and 0; (4) 850, 600 and 50. There were 16 criteria of performance. These were: No. born alive per sow bred; No. born alive per sow farrowed; No. born dead per sow bred; No. born dead per sow farrowed; No. weaned per live birth; Ave. birth wt. of live pigs; Ave. birth wt. of dead pigs; No. weaned per sow bred; No. weaned sow farrowed; Lbs. weaned per live birth; Lbs. weaned per pig weaned; Lbs. weaned per sow bred; Lbs. weaned per sow farrowed; Lbs. of feed per lb. of pig weaned; Lbs. of feed per sow bred; Wt. gain per sow. No marked differences were evident among the first three rations on the basis of the 16 rather interrelated criteria of performance. However, ration 2 was generally superior to 3 and 1. All of the first three rations were somewhat superior to ration 4 in all respects except actual weaning weight.

70 RELATIONSHIP BETWEEN BIRTH WEIGHT AND VOLUME OF MILK CONSUMED BY ARTIFICIALLY REARED BABY PIGS. David C. England, Verne M. Chapman and Patricia L. Bertun, *Oregon Agricultural Experiment Station, Corvallis.*

Consumption of milk under laboratory conditions at each of five daily feedings was measured for 5 days for each of 89 bottle fed pigs that had not nursed sows. Weights were obtained prior to first feeding and before the first unmeasured feeding after completion of five days of measured feedings. Birth weight and average consumption per feeding are highly correlated ($r = 0.83$) whereas average consumption per unit of body weight shows a negative correlation with body weight ($r = -.28$). Consumption per unit of body weight and gain per unit of body weight are positively correlated ($r = 0.59$). These data indicate that pigs of low birth weight have capacity under laboratory conditions to ingest more milk per unit of body weight than do larger pigs. Thus, the usually high mortality of low birth weight pigs is due to cause(s) other than inate capacity to consume milk.

71. NURSING POSITION OF BABY PIGS IN RELATION TO BIRTH WEIGHT. David C. England, Patricia L. Bertun, Verne M. Chapman and J. C. Miller, *Oregon Agricultural Experiment Station, Corvallis.*

Published data indicate high mortality of low birth weight pigs. Anteriorly placed udders of the sow are reported to give more milk than posterior udders. This experiment obtained nursing position of pigs in ten litters containing at least one pig with birth weight of no more than 2 lb. In only one of these litters was the lowest birth weight pig nursing the most posteriorly nursed udder. If the remainder, in four litters, the lowest birth weight pig nursed the third most anteriorly nursed udder; in three litters, the lowest birth weight pig nursed the fourth most anteriorly nursed udder and in one litter each, the lowest birth weight pig nursed the first and second most anteriorly nursed udder respectively. Two litters contained only one pig nursing posteriorly to the lowest birth weight pig. One litter contained two pigs nursing posteriorly to the lowest birth weight pig. In all other litters three, four, or five pigs nursed posteriorly to the lowest birth weight pig. In three additional litters containing no pigs of less than two pounds birth weight, the lowest birth weight pigs nursed the first and second anteriorly placed udders with four to six larger birth weight pigs nursing more posteriorly placed udders. These data indicate that high mortality of low birth weight pigs is not due to inability to compete for favorable nursing position.

72. TENDERNESS AND JUICINESS OF PORK AS AFFECTED BY PRE-SLAUGHTER INJECTION OF EPINEPHRINE. A. F. Anglemier, D. L. Crawford, R. F. Cain, and W. K. Johnston, Jr., *Oregon State University, Corvallis.*

Four barrows, weighing 220 lbs. each, were used in this study. Four hours prior to slaughter, two of these animals were injected subcutaneously with an 0.1% epinephrine solution at a dosage rate of 50 mcg. per kilo of body-weight while the two control pigs were injected with an equal volume of distilled water. Immediately after slaughter, the pH of the front leg muscles of all animals was in a narrow range of 6.72 to 6.80 whereas 20 hours later, the pH of the epinephrine treated pigs averaged 6.57 as compared to 6.08 for the controls. At the end of 48 hours, the pH of the epinephrine treated hogs was 6.43 versus 5.80 for the controls and remaining stable thereafter. The loins were aged five days at 36° F. and were then evaluated by standard organoleptic procedures. Flavor panel results showed that the loin samples from the epinephrine treated pigs were significantly more tender, juicier and had finer texture than the control samples. Tissue analysis indicated that the muscles of the epinephrine treated pigs had appreciably lower levels of lactic acid and total hexose throughout the testing period.

73. COMPARISON OF HAWAIIAN AND MAINLAND METHODS OF CUTTING PORK CARCASSES. Estel H. Cobb, Kenneth K. Otagaki, and Isaac Iwanaga, *University of Hawaii, Honolulu.*

This paper compares the Hawaiian and mainland methods of cutting pork carcasses. The Hawaiian

method differs from the mainland method primarily in the following ways: (1) The hams (legs) and shoulders are boned. The hind and front legs are removed at the stifle joint and inferior extremity of the humerus, respectively. (2) The loin is cut short compared to the mainland method by leaving the sirloin end on the ham and the shoulder end (cut between 6th and 7th ribs) on the shoulder. (3) The shoulder is not separated into the Boston butt and picnic shoulder. (4) The ribs are left on the belly and the neckbones with the attached six ribs are called the spareribs. Data from hog carcasses cut by the Hawaiian and mainland methods were used to compare the percentage yield of the major cuts under the two methods of cutting. Regression coefficients for the regression of the percentage yield of the belly, shoulder, and ham on liveweight were similar for the two methods of cutting. The regression of percentage yield of loin on liveweight was positive for the Hawaiian method and negative for the mainland method of cutting.

74. EFFECT OF ADDED FAT ON AVERAGE DAILY GAIN, FEED EFFICIENCY, PER CENT LEAN CUTS, LOIN EYE AREA AND BACK FAT THICKNESS OF SWINE. Eugene H. Rupnow and M. E. Ensminger, *Washington State University, Pullman.*

Forty hogs from the College herd were placed on test in the fall of 1959 and spring of 1960. Equal numbers of Palouse and Hampshire hogs were divided into two groups; one group receiving a control ration and the second group receiving 10% added fat in the ration, with the ration being balanced to the same protein content as the controls. The animals were slaughtered when they weighed 210 lb. The carcasses were cut 48 hours after slaughter, and the wholesale cuts were weighed; loin eye area, marbling score and color were determined on the loin at the 10th rib. Pieces of the loin were saved for determination of tenderness of the pork. The hogs receiving added fat, required less feed per 100 lb. of gain. The animals with added fat and without added fat required 3.18 an 3.51 lb. of feed per lb. of gain, respectively. The Palouse hogs had a higher average daily gain and significantly longer carcasses. The hogs receiving added fat yielded heavier carcasses; however, the fat had no effect on percent lean cuts, loin eye area, back fat thickness, length, fat trim, and tenderness of the lean as measured by the Warner Bratzler shear. The Hampshire had significantly higher (1% level) marbling scores of the lean of the loin, and this carried through to significantly more tender meat. The loin eye area was significantly different due to breed with 3.37, 3.45, 3.70 and 4.00 sq.in. for the Palouse and the Hampshire, with and without added fat in the ration, respectively.

75. TENDERNESS OF PORK AS EFFECTED BY BREED, RATION AND COOKING METHOD. Eugene H. Rupnow and Margaret Weller, *Washington State University, Pullman.*

Pork chops from 24 animals, 12 Hampshire and 12 Palouse, on a study to determine the effect of fat in the ration were evaluated for tenderness. Four 2½-in. pork chops were saved from the loin of the left side of each carcass. Two chops cut at the 11–12th and 13–14th rib were cooked by deep fat frying at 325° F. until they reached an internal temperature of 185° F. Two 1-in. cores were removed and tenderness was recorded in lb. to shear an in. core with the Warner Bratzler shear. The remaining two pieces, cut behind the 14th rib, were used to compare deep fat frying and oven cooking. Three ½-in. cores were taken from each chop. There was no difference in tenderness of the pork as a result of adding fat. The chops from the Hampshire hogs were significantly (5% level) more tender than the chops from the Palouse hogs. Deep fat frying required less time for the chops to reach 185° than did oven baking; however, the oven baked chops produced significantly more tender chops than deep fat frying. There was a highly significant difference in tenderness of the core due to position in the chops in the loin using 1-in. cores.

76. VANADIUM IN THE DIET OF THE MAMMAL. Thomas A. McPherron and Lloyd E. Washburn, *Colorado State University, Fort Collins.*

In studies with rate receiving a complete commercial ration containing 6.61 parts per million vanadium, supplementation with 2 to 20 ppm additional canadium increased feed conversion from 6.94 to 10.00% in males and from 2.27 to 10.63% in females over that of control animals. Carcasses of rats receiving vanadium were lower in fat, slightly lower in moisture and higher in protein and ash content than the controls. Intakes of over 26 ppm vanadium were toxic. Older rats tolerated 100 ppm vanadium, but this level was lethal for weaning animals. Blood calcium levels were elevated in supplemented animals, but vanadium was not detected in the blood until toxic levels in the diet were reached. Analysis of the adrenals, heart, kidneys, liver, ovaries, testes, thymus and thyroid showed that only the heart and liver of control males, and the heart, liver, kidneys and ovaries of control females contained vanadium. Highest concentations of vanadium in supplemented animals were found in the thymus, adrenals and gonads. Only the thyroid gland of supplemented animals did not contain vanadium.

77. CAROTENE UTILIZATION AND VITAMIN A NUTRITION AS INFLUENCED BY DIETARY NITRITE AND "HIGH NITRATE" SILAGE: LABORATORY STUDIES. G. S. Smith, A. L. Neumann and E. E. Hatfield, *University of Illinois, Urbana.*

Weanling male rats, depleted of liver Vitamin A, were used in a 2x2x3 factorial trial involving: (a) silage versus non-silage diets; (b) each with and without added nitrite; and (c) supplemental, preformed Vitamin A, versus supplemental beta-carotene, versus no supplemental Vitamin A activity. Corn silage (containing 1% KNO_3 equivalent, dry basis) comprised ⅓ of diet dry matter in silage diets; whereas comparable amounts of commercial chow replaced silage in non-silage diets. Added KNO_3 comprised 0.8% dry basis, of the appropriate silage and non-silage diets. Diets supplemented with performed Vitamin A or beta-carotene contained 147 I.U. Vitamin A activity (1 unit=0.3 mcg. Vitamin A or 0.6 mcg. carotene). Five rats received, *ad lib.*, each of the weight changes (gms.); plasma Vitamin A contents (mcg. %); and liver stores of Vitamin A (mcg. Vitamin A in liver per 100 gm. body weight) were as follows: *—Silage (S)—NO_3—A:*+72; 19±1; 12 diets for 25 days. Diet treatments; mean 25-day 42±12; *—S—NO_3+A:*+107; 53±6; 1149±194;

$-S-NO_3+C:+98$; 38 ± 11; 135 ± 22; $-S+NO_3-A:-47$; 14 ± 6; 4 ± 3; $-S+NO_3+A:+65$; 39 ± 17; 103 ± 16; $-S+NO_3+C:+65$; 15 ± 2; 28 ± 19; $+S-NO_3-A:+47$; 8 ± 2; 7 ± 6; $+S-NO_3+A:+61$; 24 ± 4; 1176 ± 117; $+S-NO_3+C:+51$; 22 ± 6; 84 ± 20; $+S+NO_3-A:-21$; 8 ± 5; 7 ± 6; $+S+NO_3+A:+35$; 20 ± 2; 163 ± 41; $+S+NO_3+C:+20$; 9 ± 3; 18 ± 14. In non-depleted rats fed preformed Vitamin A versus beta-carotene (40 I.U. per gm. diet) in the silage diet (without nitrite), stores were maintained by Vitamin A but decreased (11,400 versus 6,400 mcg. per liver; 4 rats each; $P<.05$) by carotene.

78. NITRATE AND NITRITE CONTENTS OF CORN FORAGES AND SILAGES AS INFLUENCED BY NITROGEN FERTILITY, SEEDING RATE, AND VARIOUS SILAGE ADDITIVES. G. W. Breniman, A. L. Neumann, G. S. Smith, and H. A. Jordan, *University of Illinois, Urbana.*

Four comparable fields were fertilized and seeded in corn as follows: I. no fertilizer, 32,000 seeds per acre; II. no fertilizer, 16,000 seeds per acre; III. 10 tons manure plus 300 pounds NH_4NO_3, 32,000 seeds per acre; and, IV. 10 tons manure plus 300 pounds NH_4NO_3, 16,000 seeds per acre. Corn silage was made from the respective plots and stored in upright silos. Samples of the fresh forages and corresponding silages (from the top, middle, and bottom of the silo) were analysed for content of nitrate and nitrite. The content of nitrate (percent KNO_3 equivalent, dry matter basis) from (a) fresh forage; (b) silage, top of silo; (c) silage, middle of silo; and (d) silage, bottom of silo was as follows: Field I (a) 0.25; (b) 0.15; (c) 0.17; (d) 0.15; II (a) 0.28; (b) 0.14; (c) 0.16; (d) 0.24; III (a) 1.38; (b) 0.98; (c) 0.54; (d) 0.73; IV (a) 0.72; (b) 0.49; (c) 0.69; (d) 0.70. In the case of Field III (forage with the highest nitrate content in the ensiled samples (percent KNO_3 equivawith various additives and placed in the silo, replicate samples being placed near the top, middle, and bottom of the silo. The treatments used and resulting nitrate content in the ensiled samples (percent KNO_3 equivalent of silage; dry matter basis; means of all replicates) were as follows with the amount of additive indicated in parentheses representing the percent of sample wet weight of forage at ensiling time: control, 0.75; calcium carbonate (1.0%) 0.48; corn grain (10.0%), 0.60; sodium propionate (0.15%), 0.82; sodium meta bisulfite (0.40%), 1.05; antioxidant (Santoquin) (0.015%), 0.64; antibiotic (tylosin tartrate) (0.02%) 0.30. Nitrite content was negligible in all fresh forage and silage samples.

79. THE EFFECT OF VANADATES ON IN VITRO FERMENTATION BY RUMEN FLORA. Lloyd E. Washburn and Bernice E. Thrall, *Colorado State University, Fort Collins.*

Increases in production of 28% for gas and 99% for volatile organic acid resulted from the addition of 2.5 parts per million ammonium vanadate to the vitro fermentation of alfalfa hay with buffered, bovine, rumen inoculum. Addition of vanadium to levels of 25, 250 and 500 ppm caused a decline in volatile acid formation and a further increase in gas production to a plateau about 39% above that of the alfalfa control. The stimulation of fermentation by vanadium, particularly at the higher levels and during the first four hours incubation, was so intense as to resemble conditions sometimes noted in bloat. The widely inconsistent relationship between gas and volatile organic acid production would appear to invalidate either, if used alone, as a reliable measurement of true digestibility.

80. A NEW SYSTEM FOR NAMING AND COMPILING DATA ON THE COMPOSITION OF FEEDSTUFFS. Lorin E. Harris and Donald F. Miller, *Utah State University, Logan.*

In the past an entire feed has been defined as a unit. This has resulted in having to memorize the entire definition of each feed and has prevented uniformity in feed terms. For example, why shouldn't "linseed oil meal" and "cottonseed meal" have the same name since they contain essentially the same parts, the seeds. The official name is "linseed oil meal" and "cottonseed meal" respectively. The new system defines each term that makes up the name of the feed. The terms in the name can be made up as follows: genus, species or product; part of plant or product; process used in preservation or manufacture; crop or cutting; stage of maturity; and official grade. By combining the terms the feed is named. Each of the terms used in the codes have been defined and codes have been developed in order that the data can be put on International Business Machine cards for summarization in terms of nutrient content. Other types of information recorded in the cards include: class, date collected, location (country, region, state, county laboratory), weight per bushel, methods of analyses, and digestibility data. By sorting the cards the data can be listed in any combination desired. Data can also be added or taken out so that information can be summarized over any period of time.

81. EVALUATION OF RANGE AND MEADOW FORAGES AT VARIOUS STAGES OF MATURITY AND LEVELS OF NITROGEN FERTILIZATION. Joe D. Wallace, C. B. Rumburg, and R. J. Raleigh, *Squaw Butte Experiment Station, Burns, Oregon.*

Samples of bluebunch wheatgrass (*Agropyron spicatum*), squirreltail (*Sitanion hystrix*), Idaho fescue (*Festuca idahoensis*), Junegrass (*Koleria cristata*), Thurber's needlegrass (*Stipa thurberiana*), and crested wheatgrass (*Agropyron desertorum*) were collected at various dates of maturity during the summer of 1959 and 1960. *In vitro* cellulose digestibility, cellulose, and nitrogen determinations were made. Cellulose digestibility and nitrogen content significantly decreased while cellulose content significantly increased with increasing maturity of the forages. Junegrass was consistently higher and Idaho fescue consistently lower than other species in cellulose digestibility. The nitrogen content of meadow forages fertilized with 0, 80, 160, 240, and 320 pounds of nitrogen per acre and harvested on May 4, May 18, June 6, June 15, June 29, and July 13, 1960 increased (early in the season) with increasing rates of fertilization, but decreased with plant maturity. The cellulose content increased with increasing plant maturity, and varied with rate of fertilization; while *in vitro* cellulose digestion decreased with incerasing plant maturity and decreased with 240 and 320 pounds of nitrogen fertilizer per acre.

NEWS AND NOTES

Meeting of the American Society of Animal Production. The 53rd. Annual Meeting will be held at the Hotel Sherman, Chicago, Friday and Saturday, November 24 and 25, 1961. Registration is from 6:00–9:00 p.m., Thursday, and 8:00 a.m. Friday. Sectional meetings Friday will be held from 9:30–11:00 a.m., and a general session at 11:00–12:00. Sectional meetings will continue Friday afternoon 1:00–4:00 p.m., and on Saturday. 9:00 a.m.–12:00, 1:00–4:00 p.m., and 7:30–9:30 p.m. The annual dinner and presentation of awards will be held on Friday, 6:00 p.m., and will be followed by the annual business meeting. A dinner for the Honor Guest will be held on Sunday, November 26.

The membership voted in favor of changing the annual meeting from Chicago at Thanksgiving to various universities in the summer. The vote was 873 for the summer meeting versus 482 for Chicago. Six votes were not counted because they were either received late or the membr failed to indicate a preference for either alternative. About 62% of the membership voted. A summer meeting cannot be held before 1963.

Your attention is called to the proposed amendment to the constitution published in News and Notes of the February issue of the Journal. The following sentence should be added to the new procedure under election of officers: "If any candidate fails to receive a majority from the mail ballot a final vote will be taken at the annual meeting." The proposed amendment to the constitution will be voted on at the 1961 meeting of the Society.

The Division of Biological and Medical Sciences of the National Science Foundation announces that the next closing date for receipt of basic research proposals in the life sciences is September 15, 1961. Proposals received prior to that date will be reviewed at the fall meetings of the Foundation's advisory panels and disposition will be made approximately four months following the closing date. Proposals received after the September 15, 1961 closing date will be reviewed following the spring closing date of January 15, 1962. Inquiries should be addressed to the Biological and Medical Sciences Division, National Science Foundation, Washington 25, D. C.

The National Science Foundation announces that September 1, 1961 is the next closing date for receipt of proposals in the Graduate Laboratory Development Program. Proposals received after September 1 will be reviewed following the next closing date, March 1, 1962. This program requires at least 50 percent participation by the institution with funds derived from non-Federal sources. Purpose of the grants is to aid institutions of higher education in modernizing, renovating, or expanding graduate-level basic research laboratories used by staff members and graduate students. Only those departments having an on-going graduate training program leading to the doctoral degree in science at the time of proposal submission are eligible at present. Proposals, as well as requests for additional information, should be addressed to: Office of Institutional Programs, National Science Foundation, Washington 25, D. C.

Dr. Stanley R. Ames, Distillation Products Industries, Chairman of the Animal Nutrition Research Council, announced that the ANRC Vitamin A Reference Standard has been accepted by the U. S. Pharmacopeia for distribution. The Standard is a gelatin-stabilized oil solution of all-trans Vitamin A Acetate with a potency of about 10,000 U.S.P. units per gram. It is packaged in units of 25 gm. and is in a form suitable for preparation of animal feeds for assay purposes. Each package is labeled with its potency and an expiration date appropriate to the specified conditions of storage. The ANRC Vitamin A Reference Standard is available on order, at $5.00 for each 25 gm. bottle, addressed to the United States Pharmacopeia, 46 Park Avenue, New York 16, New York.

Arless A. Spielman, formerly Associate Director of the Agricultural Experiment Station, University of Connecticut (Storrs), became Dean of the College of Agriculture and Director of the Agricultural Experiment Station, University of Massachusetts, on July 1. Dr. Spielman, a specialist in animal physiology and nutrition, received his B.S. degree from the University of Minnesota, his M.S. from Oregon State College, and his Ph.D. from the University of Minnesota. From 1942 to 1944, Dr. Spielman was an assistant professor of dairy husbandry at Washington State College. In 1944 he became associate professor of animal husbandry at Cornell University, and in 1947 was appointed professor and Head of the Department of Animal Industries at the University of Connecticut. He was Associate Director of the Agricultural Experiment Station at Connecticut (Storrs) from 1949 to the time of his appointment at the Massachusetts station.

Harry A. Keener, of the New Hampshire Experiment Station, succeeded Dr. Harold C. Grinnell (retired) as Dean, effective July 1. Dean Keener will continue temporarily as Director of the Station. Dr. Keener is a native of Pennsylvania and holds B.S. and Ph.D. degrees from Pennsylvania State University and a M.S. degree from West Virginia University. He has been a member of the New Hampshire University faculty for 20 years, serving first as Instructor in Animal and Dairy Husbandry, and later as Assistant Professor, Associate Professor, and Professor of Dairy Husbandry. The newly appointed Dean has been prominent for many years in the field of animal nutrition and research, and has written more than 30 scientific papers.

D. W. Colvard was formally inaugurated as 12th President of the Mississippi State University on April 15. Dr. Colvard assumed the leadership at Mississippi State on July 1, 1960. He holds a B.S. from Berea College, an M.S. in animal science from Missouri University, and a Ph.D. from Purdue University. Dr. Colvard's background in institutional administration and research includes being an instructor in agriculture and farm manager at Brevard College, superintendant of the Mountain Experiment Station for North Carolina State College, professor and head of the Department of Animal Industry at North Carolina State College, and later Dean of the School of Agriculture at North Carolina State.

Herbert H. Kramer has been appointed Director of the Nebraska Agricultural Experiment Station by the Board of Regents of the University, effective September 15. Dr. Kramer, at present Professor of Genetics in Agronomy at Purdue University, will succeed Dr. A. W. Epp who has served as Acting Director since last November, filling the vacancy occurring when Dr. E. F. Frolik was appointed Dean of the College of Agriculture earlier in 1960. Dr. Kramer is a native of Colorado and holds a B.S. degree from Colorado State University, and M.S. and Ph.D. degrees from the University of Minnesota.

Lot F. Taylor, Kansas Extension Animal Husbandman, died suddenly of a coronary occlusion on April 9. He was a native of Kansas and graduated from Kansas State College in 1931. He served his state as county agent, farm management specialist, extension animal husbandman, and was named Professor in 1951.

K. C. Fouts, former Nebraska Extension Animal Husbandman, passed away March 10 in Lincoln, Nebraska, following an extended illness. He had been associated with Nebraska extension work since graduation from the University of Nebraska in 1915 until his retirement in 1957.

Harry F. Moxley, former Animal Husbandman, Michigan Extension staff, passed away on February 18, as a result of a heart attack following surgery. Dr. Moxley retired from the Michigan Extension Service July 1, 1958, after 33 years of service. He was nationally known for many years as an authority on draft horses.

Karl G. Parker, Montana Extension Range Management Specialist, was granted leave March 15, 1961, for a two-year assignment with ICA in Paraguay.

Jorge de Alba, Head of the Animal Industry Department, Instituto Interamericano de Ciencias Agricolas, Turrialba, Costa Rica, is on leave of absence, completing a book on Animal Breeding in Latin America. Dr. John V. Bateman is in charge of the Department at Turrialba.

Mohamed M. Oloufa, Associate Professor of Animal Breeding, College of Agriculture, Cairo University, Egypt, has been in the Genetics Department, University of Wisconsin, doing research on reproductive physiology during the past year while on leave of absence. He is due back home in September, 1961. Dr. Oloufa earned the Ph.D. degree at Oregon State University in 1949.

Robert A. Alexander has accepted a position as Assistant Professor of Agriculture at Middle Tennessee State College, Murfreesboro, Tennessee effective September, 1961. He received the Ph.D. degree in Animal Science from the University of Florida in June, 1961, with a major in Animal Nutrition and minors in Biochemistry and Statistics.

Alan C. Menge joined the staff of the Rutgers University Dairy Research Farm, Sussex, July 1. He succeeds Dr. John P. Mixner who became chairman of the Department of Dairy Science in New Brunswick, July 1. Dr. Menge received the Ph.D. degree in Endocronology from the University of Wisconsin this year. His undergraduate training was at the University of Illinois and he received a Master of Science degree in Genetics from the University of Wisconsin in 1958.

Germ Plasm Resources edited by Ralph E. Hodgson: 394 pages; $9.75 ($8.50 to AAAS Members); Publication No. 66 of the American Association for the Advancement of Science, Washington, D. C., 1961. This book contains twenty-five papers in the fields of plant and animal genetics and breeding as presented at a symposium held during the 1959 meeting of the AAAS. The papers are organized under the following five headings:

I Origin of Germ Plasm
II Need for and Utilization of Additional Sources of Germ Plasm
III Developmental Programs in Crops and Livestock
IV New Approaches in the Use of Plant and Animal Germ Plasm
V Perpetuation and Protection of Breeding Stocks

This book should serve as a compact and authoritative source of information on the major developments in the fields of plant and animal genetics as well as in plant and animal breeding. Those in charge of A. I. programs should be especially interested in the chapters on elimination of defects, preservation of germ plasm, and performance testing.—W. P. G.

Handbuch der Tierzuchtung, Volume 3, part 1, Rassenkunde. Edited by Sir John Hammond, Ivar Johansson and Fritz Haring with a foreword by F. Haring; 524 pages, 350 illus.; 98 DM; Paul Parey, Hamburg and Berlin. 1961. This is the first of two books on the history, distribution, economic importance and distinguishing characteristics of the various kinds and breeds of farm animals of the world. The book was prepared by 21 persons from eight countries including two from the United States. The 21 chapters are grouped into two main sections. The first, consisting of three chapters, deals with various kinds of livestock in Europe and the distribution of horses, cattle, sheep and swine in other parts of the world. The first seven chapters of the second section deal with the various groups of equines and include a chapter each on the thoroughbred and Arabian horses, trotting horses, pleasure horses, draft horses, ponies, and donkeys including donkey crosses. The remaining eleven chapters comprising nearly three-fifths of the book are grouped under two headings: 1) types of cattle including selection goals in dairy, beef, dual-purpose and mountain cattle and 2) cattle breeds in different countries and continents. Included under the latter heading are chapters on cattle breeds in Northwest and North Europe, the Alpine countries, Italy and Spain, Eastern Europe, the Balkan countries and Asia, the United States, Canada and South America and Africa. In addition there is a chapter each on European cattle in the tropics and subtropics, and on cattle breeds developed from crossbred foundations for specific climatic conditions. The book is valuable especially for its coverage of the subject matter on a world-wide basis. It can be recommended particularly to those who are interested in breeds of horses and cattle not found in the United States. A bibliography comprising 206 books and a seven page index conclude the book.—H. O. H.

Genetic Aspects of Dairy Cattle Breeding by Ivar Johansson; 259 pages; $7.50; University of Illinois Press, Urbana, Illinois, 1961. A survey of present knowledge on genetics of economically important traits of dairy cattle and suggestions for their improvement. The first three chapters are devoted to Population Gentics and its Application to Animal

Breeding, Immunogenetics and Monozygous Twin Research. Fertility, Body Size, Growth Rate, Type, Udder Development and Milking Rate are discussed in the following four chapters. Genetic and environmental variations and covariations in Milk and Butterfat Yield and in the Constituents of Milk are the subject of two chapters. A review of such topics as Inbreeding and Crossbreeding, Estimation of Animal's Breeding Value and Progeny Testing in Practical Applications conclude this authoritive book on animal breeding.

Functional Anatomy, Mammalian and Comparative by W. James Leach; 338 pages; $6.50; McGraw-Hill Book Co., New York, 1961. This is a third revised and enlarged edition of the author's previous work, *Functional Anatomy of the Mammal.* The author emphasizes the position of morphology as being more nearly a main trunk of zoological sciences rather than representing some side branch concerned merely with the descriptive details of structure.—L. E. C.

The International Atomic Eneregy Agency (IAEA), the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) are jointly organizing a Conference on the Use of Radioisotopes in Animal Biology and the Medical Sciences in Mexico City from 21 November to 1 December 1961. Its purpose is to bring together from all over the world specialists in the fields of animal biology and the medical sciences who are interested in the use of radioisotopes. It will also serve the purpose of making medical scientists more fully aware of the potentialities of radioisotope techniques in studies on general physiology and biochemistry, and at the same time of acquainting non-medical biologists with problems relating to the physiology of disease and with clinical uses of radioisotopes. The program of the Conference covers the following topics: (1) Advances in radioisotope technique and methodology as applied in the biological sciences and medicine. (2) General physiology, biochemistry and metabolism, including: structure, function and biosynthesis of biologically important compounds; intermediary metabolism, biochemistry as related to genetics. (3) Mineral metabolism, including: digestion, absorption and transport; biochemical and physiclogical function of minerals; trace elements. (4) Skeletal physiology, including; calcium and phosphorus deposition in bone; strontium deposition in bone, remodelling; skeletal physiology and disease. (5) Physiology of reproduction, including; duration of spermato-genesis and oogenesis; artificial insemination. (6) Physiology and biochemistry of the ruminant animal, including: digestion and synthesis, rumen microflora; rumen fluids; cobalt, copper and other minerals. (7) The physiology and biochemistry of lactation, including: synthesis and transport of milk precursors; synthesis in the mammary gland and secretion of milk; the intermediary metabolism of sugar, fat, amino acids and proteins. (8) Glandular function, endocrinology, including: the biochemistry of hormone production; transport and metabolism of regulators; correlation of glandular activities. (9) Poultry: physiology, nutrition and pathology. (10) Microbiology and immunology. (11) Haematology including animal and comparative haematology. (12) Dentistry. (13) Clinical research, including: body composition and electrolytes; metabolic studies; absorption studies; circulation studies; localization studies. Further information may be obtained from the Joint IAEA/FAO/WHO Secretariat of the Conference on the Use of Radioisotopes in Animal Biology and the Medical Sciences, International Atomic Energy Agency, Kaerntnerring 11, Vienna, Austria.

INFORMATION FOR CONTRIBUTORS

1. Papers may be submitted reporting work whose ultimate objective is clearly the solution of a livestock production problem and whose contents should be of interest particularly to those dealing with livestock production problems. Review papers on subjects of general interest will also be published at intervals. These will be prepared on invitation of the Editorial Board.

2. All papers will be subject to critical review by the Editorial Board, or others designated by the Editor. Papers needing revision will be returned to authors and should be revised and returned promptly. Papers not suitable for publication will be returned to authors with a statement of reasons for not accepting them.

3. Papers submitted should be based on new and adequate information. The primary purpose of a scientific publication is to provide information based on well-described data and to exchange ideas. Authors are therefore discouraged from submitting for publication results of research involving products whose ingredients cannot be disclosed. Information on composition and source of any product which may have a bearing on the experimental results should be provided. Authors are also discouraged from submitting papers based on routine product testing.

4. Consult a recent issue for style and form. The following are guides:

   (a) Manuscripts must be typed, double-spaced and the ribbon copy submitted. Submission of two copies (one carbon) will facilitate review.

   (b) All pages, including those of tables and legends, must be numbered. The lines of the text, but not of tabular material or "Literature Cited", must be numbered in the left margin, beginning with one at the top of each page.

   (c) Tables should be as few and as simple as is feasible for presentation of the essential data. Each table should be on a separate sheet.

   (d) The legend for each figure should be typed on a separate sheet. Photographs should be carefully prepared and labeled. Magnification of photomicrographs should be indicated on legends. Charts should be prepared in India ink. Typed material on charts is not acceptable. Material that will not reproduce satisfactorily will be returned for revision. For suggestions on preparing illustrative material see the "Style Brief" published by the Wistar Institute Press, Philadelphia. If in doubt, consult the Editor before putting material in finished form.

   (e) The introduction should consist of no more than 200 words indicating very briefly the nature of the questions asked and the reasons for asking them. Most of the relevant literature should be mentioned later in the discussion of the results. Concise presentation of data is desired and there should be evidence of statistical examination wherever obviously useful in the interpretation. Unsupported hypotheses should be avoided. The organization of a manuscript may vary with the nature of the material, but manuscripts should contain a statement of application of the results or their relation to some problem of the livestock industry. Each paper should end with a summary in the form of an abstract containing the most pertinent data in the briefest possible form.

   (f) Literature citations must be listed in alphabetical order and should be referred to in the text by author and date, i.e., Castle (1924) or (Castle, 1924); Best *et al.* (1951) or (Best *et al.*, 1951). Citations may be referred to by number in review articles where the number of citations is too great to permit convenient use of the above form. "Literature Cited" lists should be typed in a style used in a current issue of the JOURNAL.

5. Manuscripts will be edited in the order received, and accepted papers will be published as nearly in this order as feasible.

6. There will be a charge for making engravings in excess of the equivalent of one column per paper and of printing tables in excess of the equivalent of two columns per paper. The author will be asked when his manuscript is accepted to indicate the institution, agency or individual responsible for the charges and for the reprints ordered at that time.

7. Authors will receive galley proof of articles together with a form for supplying an abstract for "Biological Abstracts". *Corrected proof and abstract should be mailed to the Editor within three days after they are received. Failure to do this may result in delay of publication until the next issue.*

8. One author of each manuscript should be a member of the Society. Papers by non-members can be published only after approval by the Executive Committee.

9. A "News and Notes" section will be published in each issue, including Society announcements, changes in positions and other items of professional interest to members. All such items should be sent promptly to the Editor.

10. Abstract of papers to be presented at the annual meetings of the Society will be published in the November issue. Such abstracts must not exceed 250 words in length, should be typed (double spaced) and the ribbon copy submitted, the lines on the page should be numbered, in the left margin, from top to bottom, and must be in the hands of the Secretary of the Society by August 15, preceding the meeting. These abstracts must be summaries of results and conclusions. They should be checked carefully before submission—proofreading of the galleys will usually not be possible.

11. Presentation of a paper at the annual meeting does not exclude it from publication in complete form in the JOURNAL. Such papers may be submitted to the Editor and will be given equal consideration with others submitted.

12. All manuscripts and correspondence concerning them should be addressed to the Editor: A. B. Chapman, Department of Genetics, University of Wisconsin, Madison 6, Wisconsin, or to the publisher: Boyd Printing Company, Inc., 49 Sheridan Ave., Albany 10, N. Y.

13. All correspondence concerning subscriptions to the JOURNAL OF ANIMAL SCIENCE and other business matters should be addressed to the Business Manager, C. E. Terrill, Animal Husbandry Research Division, Agricultural Research Center, Beltsville, Maryland, or to the publishers, Boyd Printing Company, Inc., 49 Sheridan Avenue, Albany 10, N. Y.